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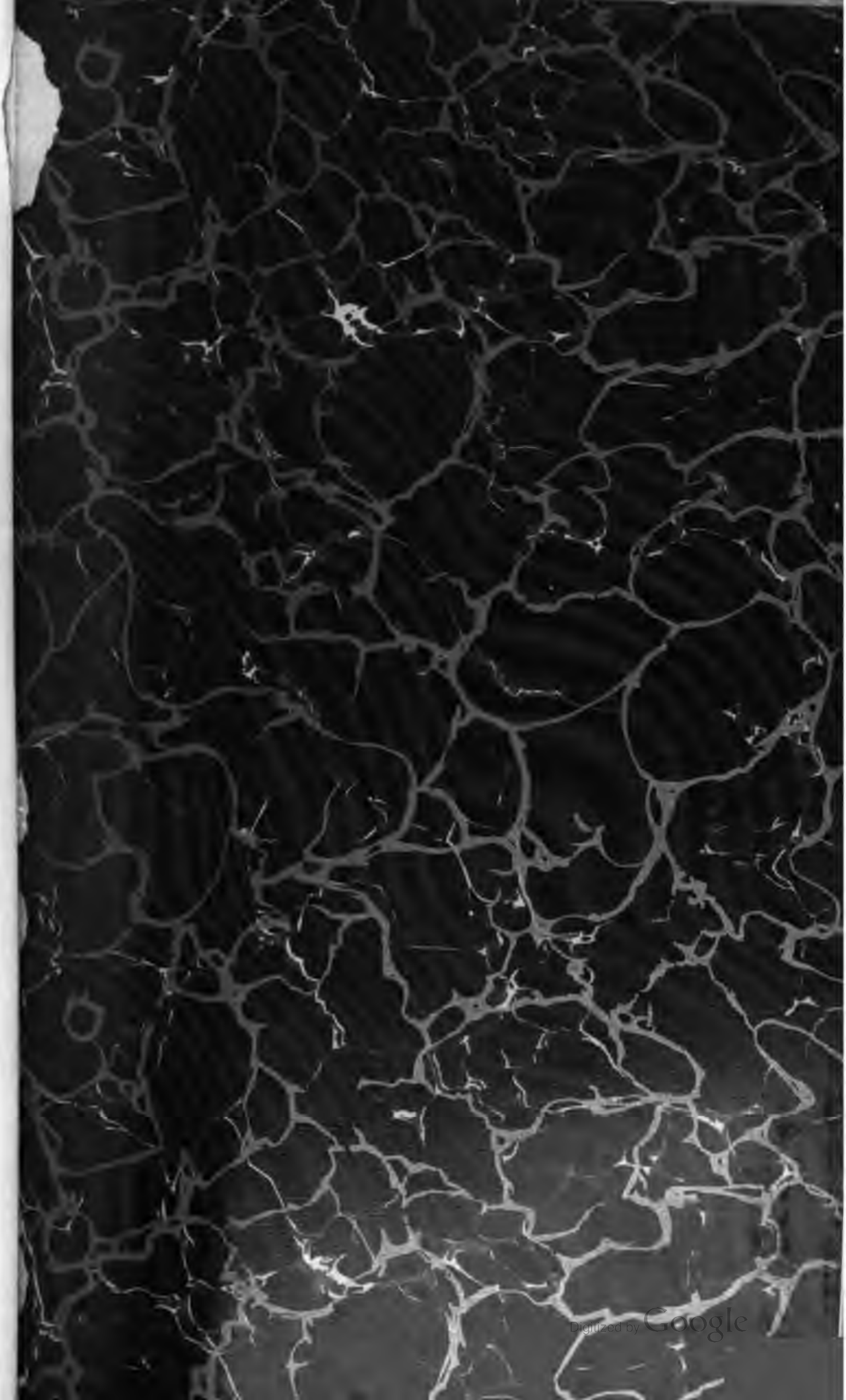

A SYSTEM

OF

ELECTROTHERAPEUTICS

INTERNATIONAL CORRESPONDENCE SCHOOLS
SCRANTON, PA.

PHYSICS OF ROENTGEN RAYS
SKIAGRAPHY
PRACTICAL APPLICATIONS OF ROENTGEN RAYS
PHYSICS OF LIGHT AND CAUTERY

SCRANTON
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THE PHYSICS OF ROENTGEN RAYS.

INTRODUCTION.

1. As this is written with the specific purpose of explaining the production and utilization of the Roentgen rays for practical purposes only, it is not the intention to go into the theory or history of the apparatus required, but rather to limit the descriptions to *how* to use the same, instead of finding out *why* it acts in this or that manner. This does not mean that no explanation whatever will be given of the various apparatus used, but, rather, that such descriptions will be limited to the elucidation of the most essential parts.

So many methods and instruments have been used and recommended for Roentgen ray work that to do justice to these, even by a most condensed description, would only be confusing to the student, and would prevent him from fastening his attention to the more important parts. Fortunately, during the last year there has been a very active weeding-out process in operation, with the result that the efforts toward improvement and progress have been crystallized more or less around the vital points, instead of wasting energy and expense in seeking advantage in methods that, in reality, would be in a retrograde direction. In consequence of this elimination of non-successful apparatus, it will be easier for the student to get a free view over the field and to avoid instruments that, though made at a large expense and for which great claims may be made, in reality, are less serviceable than cheaper instruments built on more rational principles.

2. Classification of Apparatus.—To facilitate the understanding of the leading principles in Roentgen ray work, we will,

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before proceeding to a more detailed description of apparatus, first give a general view of the whole *modus operandi.*

The Roentgen rays, which proceed from a vacuum tube, are in reality the final transformation of electric energy, derived from any suitable source. First, then, we require means for converting mechanical or chemical energy into electric energy or an opportunity for receiving such energy already at hand.

1. *Sources of Electric Energy.*—Among these may be counted ordinary voltaic cells, accumulators, dynamos, and, derived from the latter on a larger scale, the ordinary street current as used for lighting purposes. Finally, the static induction-machine.

This energy, delivered in the form of an electric current, except that derived from a static machine, is not in a condition and has not the properties requisite for the production of Roentgen rays. It has to be changed, or transformed, and for this purpose sent through what are termed *transformers.*

2. *Transformers.*—Among these the induction-coil occupies the first place. By its means the current of low pressure is changed into an intermittent one of many times higher pressure. With the static machine no transformer is required, as the current derived from it is already in possession of so large a pressure that a further increase of the same is unnecessary.

Having obtained an electric current of the requisite pressure and volume, it will now have to be transformed into Roentgen rays by means of the Roentgen ray tube.

3. *Roentgen Ray Tube.*—This receives the electric current and transforms it into ether waves of extremely high frequency, much higher than ordinary light, and of much shorter wave-lengths. We have then Roentgen rays.

These, in themselves, are invisible to the human eye, and means must be found to change their wave-lengths into a form to which the eye is able to respond. Various salts are able to do this and when they are used as a coating on screens of suitable form, we have what is termed a *fluorescent screen.*

4. *Fluoroscope.*—A screen placed at one end of a tapering box with an aperture at the other end, allowing the eyes to observe the screen and preventing ordinary light from reaching

either the rear side of the screen or the eyes, constitutes what is ordinarily called a *fluoroscope*. Large screens are also used separately; then the whole room must be darkened. The utilization of the fluoroscope in examining the conditions and actions of parts of the human body is called *fluoroscopy*. When it is a question of recording the shadows made visible by the fluoroscope, we have to deal with *skiagraphy*.

5. *Skiagraphy*.—This process is, in reality, simply photographic, because the means used in recording the shadows are the ordinary sensitive plates used in every-day photography. Many of the plates used are especially made for Roentgen ray work, but even then the process of developing and fixing are identical with those of ordinary photography. The final process of reproducing the negative on various photographic printing papers comes under the head of pure photography, but will be included here so as to describe the Roentgen ray manipulations in their entirety.

SOURCES OF ELECTRICAL ENERGY.

VOLTAIC CELLS.

ELECTRICAL UNITS AND TERMS.

3. Pressure and Rate of Flow.—Before proceeding to consider the various voltaic cells, it may be well to first mention the main properties of the electric current. The amount of electrical energy of which the current may be in possession depends on two factors, *pressure* and *rate of flow*. The comparison of a current of electricity with a current of water may assist in understanding the influence of these factors on the character of the current.

For instance, a high waterfall may send a relatively small quantity of water through a tube and supply a small turbine or Pelton waterwheel below with several hundred horsepowers. On the other hand, we may see a river with a low dam sending a large volume of water through several large turbines. The power developed in either case may be the same, but what the latter arrangement lacks in pressure it has to make up in the rate of flow.

In the flow of the electric current, we find these same differences caused by pressure and rate of flow. For some purposes, as, for instance, operating a Roentgen ray tube, a current is required of very high pressure, and relatively small strength, while for others, such as electroplating, a current of great strength, but of very low pressure, is more suitable.

4. **Electromotive Force.**—While the term *pressure* is largely used when referring to an electric current, it is customary to also use the terms *voltage*, *tension*, and *electromotive force.* The latter is usually abbreviated to E. M. F. As a unit for measuring the pressure, the *volt* is used, and the amount of pressure ascertained by the use of a *voltmeter.*

5. **Amperage.**—In place of the term *quantity*, or *rate of flow*, when speaking of an electric current, it is common usage to employ the terms *amperage*, *strength*, or *intensity.* As a unit, we employ the *ampere*, and find the amperage of any current by means of an *ampere meter*, or, as usually abbreviated, an *ammeter.*

6. **The Watt.**—That amount of energy of which any electric current is in possession, depends on the product of its amperes and volts. The unit of electric power is the *watt* and is 1 volt × 1 ampere; 746 watts constituting 1 horsepower. For instance, a current may have a pressure of 10 volts and a strength of 5 amperes; then its power is $10 \times 5 = 50$ watts. The voltage and amperage may be varied infinitely, but as long as the product of the two remains constant, the power is the same. Thus, a current of 500 volts and .1 ampere is of the same power as one with .2-volt pressure and 250 amperes strength. In both cases the product is 50 watts.

7. **Resistance.**—A current of water flowing through a tube is subject to a loss of pressure by reason of the friction between the fluid and the walls of the tube. It may, therefore, reach the end of the tube with only a small fraction of the pressure that it originally possessed. An electric current is also subject

to such resistance when passing through a conductor, and will lose more or less in pressure, depending on the nature and dimensions of the conductor.

8. **The Ohm.**—The amount of electric resistance by which a conductor obstructs the passage of an electric current is expressed in *ohms*, which is the unit of resistance. The more ohms resistance a conductor possesses, the more extra or surplus pressure the current must have in order to reach the end of the conductor with a sufficient voltage to do the work required of it. All conductors offer *some* resistance, but when the same are short and of large diameter, the resistance may be so small as not to require consideration, while, on the other hand, when the conductor is long and of small diameter, as in an induction-coil, the loss may be very great.

9. **Loss in Voltage.**—The loss in voltage that an electric current suffers when overcoming resistance is usually transformed into heat, and if this heat is excessive, it may carbonize the insulating covering of the conductor, or it may even rise to such a height as to melt the conductor.

10. **Positive and Negative.**—A distinction is made in the direction in which the current is flowing. When the current is flowing *out* of a conductor, it is said to flow in a positive direction, and the end from which it issues is called the *positive terminal*, or *pole*. When flowing *into* a conductor, it is going in a *negative* direction and that end of the conductor is the *negative terminal* or *pole*. These distinctions hold true whether cells, dynamos, induction-coils, or static machines are considered. In these sources of electric energy, those parts from which the current emerges are always called the *positive* terminals, binding-posts, or poles, whatever term applies to the apparatus in question. The other terminal, then, is *negative*.

11. **Anode and Cathode.**—When considering apparatus in which an electrolytic action takes place, or when the current is sent through a vacuum tube, it is customary to term the positive pole an *anode*, and the negative, a *cathode*.

12. Direct and Alternating.—So far we have supposed that the electric current was continuously flowing in the same direction. This is not always the case; it may be that it periodically changes its direction in the same manner as a pendulum, oscillating backwards and forwards. A current of this nature is called *alternating*, while one that does not change its direction is termed a *direct* current.

13. Connections.—If an electrical device is to be connected with a source of electric energy, such as an induction-coil with a storage-battery, the *positive* terminal of the source is connected with the *negative* terminal of the device in which the energy is to be utilized, so that the current passes *from* the source *into* the receptive device and then again *from* the latter *into* the negative terminal of the former.

SIMPLE VOLTAIC CELL.

14. Parts of a Voltaic Cell.—We may, in a general way, speak of the sources of electric energy as sources of electric pressure. Whenever an electric pressure has been produced, a current will flow, if it is given a free path, and the strength of the current will be governed by the resistance it finds in its path or circuit. As an elementary example of such sources of pressure we may take the fundamental *voltaic cell.*

It consists, as illustrated in Fig. 1, essentially of a vessel *A* containing saline or acidulated water, in which are submerged two plates of dissimilar metals *C* and *Z*, or one metal and a metalloid.

The two dissimilar metals, when spoken of separately, are called *voltaic elements;* when taken collectively they are known as a *voltaic couple.* An *electrolyte* is a compound chemical substance in solution, and which undergoes decomposition when traversed by an electric current. A *voltaic battery* is a number of simple voltaic cells properly joined together. The *terminals* of a cell are the parts of the plates outside of the electrolyte.

It should be remembered that the polarity of that end of the plate or voltaic element that is acted upon by the electrolyte is always of opposite sign to its terminal. For instance, in the case of the zinc-and-copper couple illustrated in Fig. 1, the terminal of the zinc plate *Z*, or that part outside the electrolyte, would be spoken of as the *negative* terminal, while that part of the copper plate *C* outside the electrolyte would be spoken of as the *positive* terminal. When mention is made of the positive or negative pole of a cell, reference is always had to the exposed part of the elements, and no attention is paid to the submerged parts. The symbols + and − refer to the parts of the elements not contained in the electrolyte, and are always of the opposite sign to the parts submerged in the electrolyte.

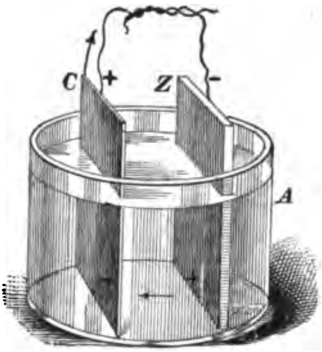

Fig. 1.

15. Chemical Action Occurring in a Simple Cell. As soon as exterior connection, by means of a wire, is made between the two plates, the plate of zinc *Z* is attacked by the acid and a part of it dissolved into a salt of that metal called *sulfate of zinc*. Large quantities of hydrogen gas are liberated around the copper and come to the surface at that point. The chemical energy liberated by the zinc is transformed into electrical energy, with the result that a difference of electric pressure or potential is created between the two plates. This difference causes an electric current to flow from *C* to *Z* through the wire in a direction corresponding to that of the arrow. A removal of the wires will interrupt the current, but the pressure will still exist, ready to continue the current as soon as the opportunity offers itself.

16. Ohm's Law.—The amount of current that a cell is able to furnish depends on its pressure, or E. M. F., and the resistance of the circuit. That is to say, the current is directly proportional to the E. M. F. and inversely to the resistance of the circuit. Arranging these relations in the form of an equation, we have the fundamental *Ohm's* law, which is: current $= \frac{\text{E. M. F.}}{\text{Resistance}}$. Usually this is abbreviated to the form: $C = \frac{E}{R}$, in which C stands for current, E for E. M. F., and R for resistance.

COMBINATIONS OF CELLS.

17. Main Principles.—Whenever the voltage or amperage of an electric source, such as a voltaic cell, is insufficient, a combination of several such cells may be made either for the purpose of increasing the voltage, or the amperage, or both.

Let us take an example from every-day life to make such a combination more easily understood. Suppose we have a long ladder leaning against the side of a high building, and that on this ladder are situated about 20 men that are engaged in passing a bucket filled with water, from hand to hand, until it reaches the top, where it is emptied into a pipe reaching down into the cellar. When this tube is full and maintained so, the column of water that it contains will evidently be in possession of a high pressure at its base, so that a motor situated in the cellar may be operated by it. In this instance we have 1 bucket on which each man in succession expends a certain amount of power, each adding gradually to the amount of potential energy of which it is in possession, until it reaches the top and has received its maximum energy.

Now, let the men descend and place themselves side by side in one row and let each one be provided with a bucket that he is required to fill from a large tank, to lift shoulder high, and empty into a common trough. From the latter the water flows toward a small waterwheel, which is set in rotation. In this combination we have 20 buckets lifted to the same height and contributing to *one* stream, while in the first instance 1 bucket is lifted to a height 20 times greater and only delivering a quantity of water corresponding to that of 1 bucket. These two arrangements are not the only ones possible, a combination of the two may be effected in many variations, such as 4 men high in 5 rows or 10 men high in 2 rows, etc., in either case varying the final pressure and rate of flow.

Having familiarized ourselves with these preliminaries, we can now easily understand the effect produced when voltaic cells or other electric sources are arranged in various combinations.

18. Cells in Series.—Let Fig. 2 represent 4 voltaic cells in which *a* are positive and *b* negative terminals. If, now, the cells are connected by means of short wires *c* in the manner indicated, it is clear that the current from cell c_4, say 2 amperes, will pass in succession through each of the cells c_3, c_2, and c_1, similar to the one pail of water lifted in succession by 20 men. The quantity of water remained the same, but an increase in energy was supplied by each man. We have here the current remaining of the same strength, being that of the one cell c_4; but each cell emits the current with its own pressure, that of 2 volts, added to it. The current will, therefore, leave the cell c_1 with 4 times the pressure it had in cell c_4, or 8 volts, but it will show no increase in strength or amperage. When cells are arranged in this manner, they are said to be arranged in *series*.

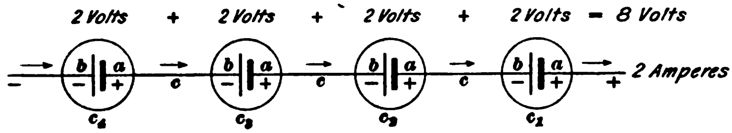

FIG. 2.

19. Cells in Parallel.—Now let the cells be arranged so as to correspond with the combination when all the men were standing side by side in one row, each provided with a bucket. This is shown in Fig. 3. Here all the positive poles *a* are united by the connectors c_1 to a common conductor *d*. All four cells are now sending their individual

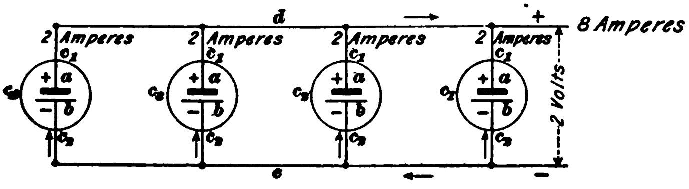

FIG. 3.

currents of 2 amperes to *d*, where they are united into a current 4 times the strength or amperage of each cell, but only with the voltage of one cell, or 2 volts. The current returns to the cells through conductor *e* and connectors c_2. When thus combined they are in *parallel* or *multiple*.

20. Difference Between Combinations in Series and Parallel.—Arranging the cells in *series* we have the current increased in *pressure* in proportion to the number of cells included, but no gain in amperage. On the other hand, when placed in parallel, the current strength, or the *amperage*, is increased corresponding to the number of cells combined, but no gain in pressure is obtained.

21. Combination of Series and Parallel.—By combining the two arrangements, as in Fig. 4, we may obtain an increase in both amperage and voltage, depending on the number of cells included and the manner in which they are arranged. In Fig. 4, cells c_1 and c_3 are placed in *series* and, likewise, c_2 and c_4, and these two rows are combined in *parallel*. Such combinations are called *parallel series*. Either of the series c_1, c_3 or c_2, c_4 multiplies the pressure by 2, producing 4 volts, but leaving the amperage unchanged, while the two rows combined send a current of twice the strength of one cell or 4 amperes, through conductor *d*. In all the figures, + and — signs indicate the polarities, and arrows, the directions of the currents.

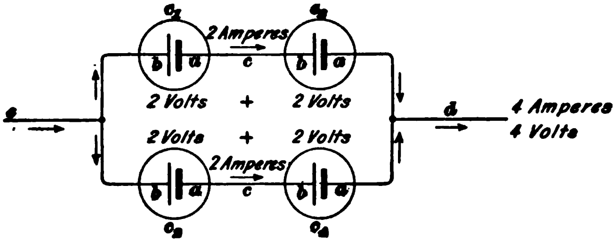

FIG. 4.

22. Ampere-Hours.—When reference is made to *ampere-hours*, it is to be understood as meaning the number of hours that a voltaic or storage cell will deliver a current of a certain amperage, which, again, will depend on its capacity. For instance, 100 ampere-hours may mean 1 ampere for 100 hours, 2 amperes for 50 hours, 4 amperes for 25 hours, and so on. How much the amperage may be increased beyond this will depend on the construction of the cell or accumulator. Some may safely deliver a much heavier current, while others may not, and would be ruined in so doing.

COMMERCIAL VOLTAIC CELLS.

23. Edison-Lalande Cell.—If the manipulator of a Roentgen ray apparatus is situated away from large cities, in a place where the electric current cannot be furnished from a central station, he may be obliged to fall back on those sources of electrical energy that formerly were used almost exclusively, that is, on the voltaic cells. Some of these offer less convenience than others, but they all suffer from the same fault, that of being comparatively expensive in their maintenance and more or less troublesome. There are few among the various varieties of primary or voltaic cells that are suitable for the heavier work of supplying the necessary current for an induction-coil. Among these may be mentioned first, as one of the most efficient, the *Edison-Lalande* cell. This is made up of a plate of cupric oxid held in copper frames enclosing the edges of the plates. The positive element of the cell is zinc, and the electrolyte a solution of potassium hydrate, or caustic potash. Two plates of zinc are used in most forms of this cell, one on each side of the cupric-oxid plate.

A cell of this type, having a capacity of 150 ampere-hours, is shown in Fig. 5. The cupric-oxid plate *C* is suspended in a copper frame *F*, *F* between the two zinc plates *Z*, *Z*, which are hung from each side of a lug on the porcelain cover of the jar. The sides of the copper frame of the oxid plate are carried through the cover supporting the plate, and form terminals *B*, *B*, either of which may be used as the positive terminal of the cell. That part of the copper frame which projects above the plate *C* is protected from the action of the liquid by tubes of insulating material *T*, *T*. A binding-post B_1, on the bolt that supports the two zinc plates, serves as the negative terminal. A layer of heavy paraffin oil is used in this cell to prevent the action of the air on the solution, and also to prevent the solution from creeping up the zinc plates.

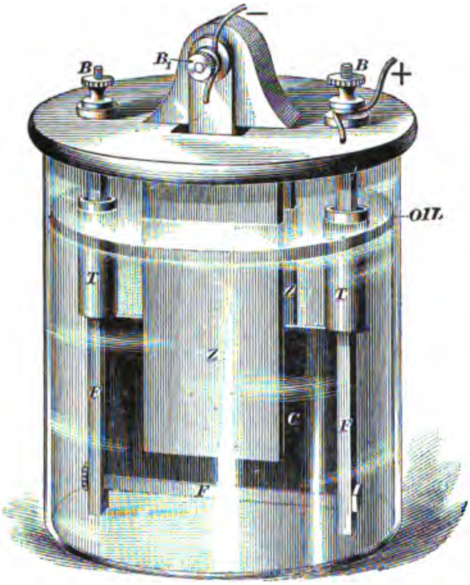

FIG. 5.

The 150-ampere-hour cell, shown in Fig. 5, will give a current of 3 amperes at a pressure of about .7 volt for 50 hours, with one "charge" of zinc, caustic potash, and oxid. They are very constant and are able to furnish a large current. Larger sizes will furnish the same current at the same pressure for 100 or 150 hours, respectively. They may deliver 6 amperes, if necessary.

24. The Harrison Cell.—Another cell capable of a large current is the *Harrison cell*. Its positive element is granulated zinc in an electrolyte of dilute sulfuric acid. The negative element is surrounded by a peroxid of lead. The voltage is 2.7 and the internal resistance 1 ohm. The capacity of the No. 3 cell is 300 ampere-hours.

25. The Grenet Cell.—Still another cell, which may be used, is the *bichromate*, or *Grenet* cell. This cell will not work as long before it needs recharging, but will demand this after a continued service of 2 hours, if it furnishes the current for an 8-inch coil.

This cell may either be arranged in single units and connected in series, or it may be made into the form of a *plunge-battery*, when all the elements are fastened to one common bar, which will simultaneously lift them out of the electrolyte when the battery is to be put out of action.

Fig. 6 shows the familiar type of the Grenet cell. It consists of a bottle-shaped jar with a hard-rubber or porcelain cover, from which two flat carbon plates *C*, *C* are suspended parallel to, and a short distance from, each other. Between them hangs a zinc plate *Z*, supported by a sliding rod *R*, that may be drawn up until the zinc is entirely out of the liquid. This rod is held in any position by the thumbscrew *T*. On top of the brass rod is a binding-post B_1, the other terminal of the cell being the binding-post *B*, which is connected to the two carbon plates *C*, *C*. The electrolyte is composed of 3 parts of potassium bichromate dissolved in 18 parts of water to which is added 4 parts of sulfuric acid. The E. M. F. of the cell is 1.92 to 2 volts.

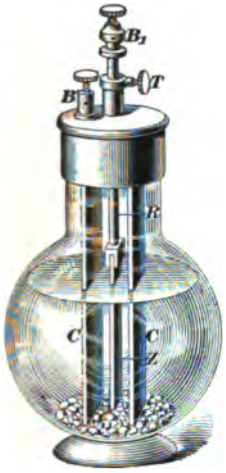

FIG. 6.

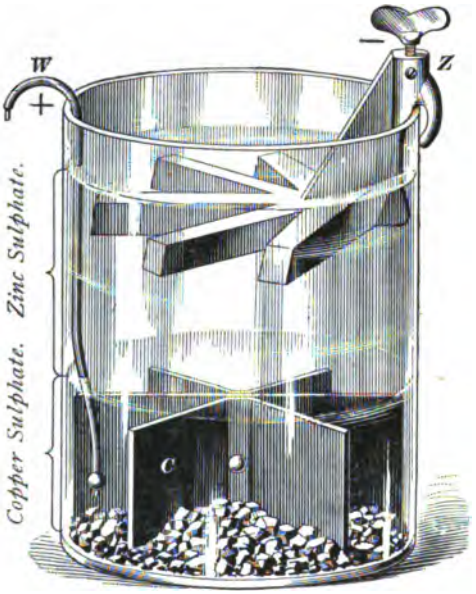

FIG. 7.

26. The Gravity Cell.—Another form of cell that is quite useful, is the so-called *gravity*, or *crowfoot*, cell, illustrated in Fig. 7. The zinc *Z*, from the shape of which the cell has received its name, hangs from the edge of the glass jar; the copper *C* is connected to the external circuit by the wire *W*, which is covered with an insulating material on those parts submerged in the liquid. When the cell is set up, the copper plate is surrounded with crystals of cupric sulfate until it is completely covered. The zinc weighs about 3 pounds, and 2 pounds of cupric-sulfate crystals are required to charge the cell. The E. M. F. is about 1.07 volts. The maintenance of this cell is simple.

27. Bunsen Cells.—Bunsen cells have also been used for operating coils, but they are rather objectionable on account of their odor.

Voltaic cells are at present rarely used for heavy work, but rather more for charging accumulator, or storage-batteries. They can then do their work more slowly, without being strained to their utmost capacity, and at a higher efficiency.

ACCUMULATORS, OR STORAGE-BATTERIES.

CLASSES.

28. Difference Between Primary Cells and Accumulators.—There is this difference between a primary and a storage, also called a secondary, battery, that while the first is able to furnish an electric current primarily as a result of chemical action taking place in the battery, the storage-battery, on the other hand, must first have a chemical action produced in it by means of an outside electric current. After this action has been completed, the source of electrical supply is disconnected. The battery is now seeking to return to its original chemical condition, and will, in doing so, return the greater part of the current that was sent into it and caused said chemical decomposition. We see, then, that it is not electrical but chemical energy that is stored in the battery, and that it is this energy that is changed into electrical energy.

An advantage of the storage-battery over the primary battery is that in the former the rate of this transformation can be varied within wide limits and heavy currents furnished for short lengths of time that would be far beyond the capacity of a primary battery of the same size.

Whenever it is possible to have storage-batteries conveniently charged, they are to be preferred to primary batteries for the purpose of operating an induction-coil.

In case an incandescent-lamp circuit is not available for charging storage-batteries, then a compromise must be made and some style of primary battery used for the purpose.

29. Chlorid Accumulator.—There are various classes of accumulators in the market of more or less efficiency, but, for Roentgen ray work, the *chlorid* accumulator has so far been used almost exclusively and has given very good satisfaction. It has the advantage over the older forms of the Planté and Fauré class that it will stand harder usage and give a heavier discharge without any liability to distortion or *buckling*. With ordinary care they will last for years.

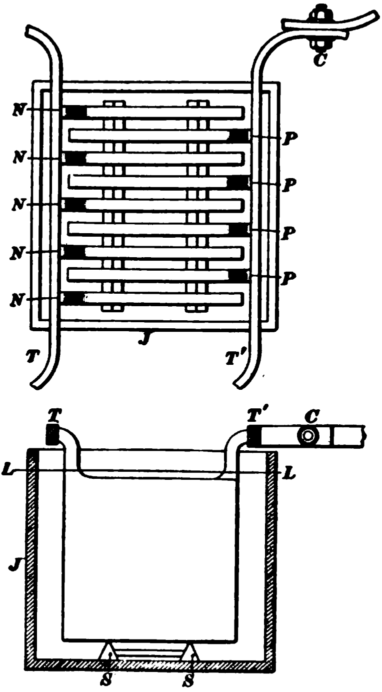

FIG. 8.

The plates of this type of storage-cells are made as follows: A mixture of zinc chlorid and lead chlorid is melted and run into molds that form it into cylindrical pellets, or pastils. The pellets are placed in a second mold, and an alloy of lead and antimony is melted and forced between the pellets under heavy pressure. When this cools it forms a plate, binding together all the pellets of zinc and lead chlorid. After being given some supplementary treatment, the requisite number of plates are set up together to form a cell, positive and negative alternating, and connected to common conductors as shown in Fig. 8, where the plates marked *N* are negative and those marked *P* are positive. The number of negative plates is always one more than the number of positive plates, so that *each* side of each positive plate has presented to it the surface of a negative. From a corner of each plate a lug projects; the lugs on the nagative plates are joined to a connecting strip, as represented at *T*, and the lugs on the positive plates are similarly joined to a connecting strip *T′*. These connecting strips are extended beyond the limits of the cell, and serve to connect the various cells of the battery together, as shown at *C*, the connection being made by a brass bolt, which firmly clamps the connecting strips together.

The plates are placed in the jar *J*, and they rest on a support made from two strips of wood (usually boiled in paraffin) of triangular section *S*, *S*. These support the plates at such a height that any loosened particles of active material fall below the level of the bottom of the plates, thus preventing possible short-circuiting. When in position, the electrolyte is poured in until it reaches the line *L L*, thus covering the plates. The plates are usually kept separate by blocks of insulating material.

These accumulators are classified under various types and the selection of the proper type depends on the work they will have to perform.

The following data regarding the type D_5 may be of interest. The normal charging rate of the same is 5 amperes; when discharging, it may do so in:

8 hours at the rate of 5 amperes = 40 ampere-hours.
5 hours at the rate of 7 amperes = 35 ampere-hours.
3 hours at the rate of 10 amperes = 30 ampere-hours.

Of course, it may be discharged at any desirable rate below 5 amperes, when its ampere-hours will be correspondingly increased. It is seen that by increasing the rate of discharge its total capacity is decreased. The charging current of these cells is about 1 ampere for each 12 square inches.

30. Charging Accumulators.—When an accumulator is connected with a source of electric energy, such as a voltaic battery, for the purpose of being charged, its *positive* terminal should be connected to the *positive* terminal of the battery. In charging 5 cells of this class by means of primary cells, 15 such as the Harrison type may be required, arranging them in groups of 3 in parallel and 5 of these groups in series. They would then be able to send a current of 4 amperes through same. It is supposed that the capacity of the latter is 40 ampere-hours. By adding 10 per cent. to this, making a total of 44 ampere-hours, we will find the time required for charging to be $\frac{44}{4} = 11$ hours. The capacity of these primary cells being 300 ampere-hours, they would be able to maintain a charging at this rate for about 225 hours.

As a further example of charging accumulators, let us suppose that the latter consists of 8 cells with a maximum voltage of 2.5 volts per cell. Total voltage will then be: $2.5 \times 8 = 20$ volts. If the cells be discharged down to 1.8 volts per cell, below which point the discharge should not continue, then the minimum voltage would be $1.8 \times 8 = 14.4$ volts.

31. Counter Electromotive Force.—The E. M. F. of the accumulator when acting in opposition to that of the charging current is called a *counter* E. M. F. In this instance, the counter E. M. F. is 14.4 volts at beginning of charge, increasing to 20 when the charge is completed. The internal resistance of these cells being low, the charging cells should also be so and with a high E. M. F.

32. Examples of Charging.—For charging purposes we may also select those of the *gravity* class, of which many good varieties are in the market, or *bichromate* cells. Utilizing the latter, in which each cell has an E. M. F. of 1.5 volts and .06-ohm resistance, and taking 14 cells, the total E. M. F. would be $14 \times 1.5 = 21$ volts, with an internal resistance of $14 \times .06 = .84$ ohm. Letting the total resistance of the primary and storage cells amount to 1 ohm, we would, if all the cells were placed in series, have a current at starting, as follows:

$$C = \frac{21 - 14.4}{1} = 6.6 \text{ amperes.}$$

When the work of charging is nearly completed the current will be

$$C = \frac{21 - 20}{1} = 1 \text{ ampere.}$$

Estimating the average charging current to be 3.5 amperes and the ampere-hours at 180, and adding 10 per cent. to the latter, we find the time required to be $\frac{198}{3.5} = 62$ hours.

By increasing the number of cells to 25, their total voltage would be $25 \times 1.5 = 37.5$, and the average current-strength 12.25 amperes. The charging would now be complete in about 15 hours.

33. Gassing.—When the charging is complete, the hydrogen and oxygen gases, which are developed by the current, can no longer be taken up and chemically combined with the plates. They will therefore escape; the so-called "gassing" takes place and the water assumes a milky appearance. Continuing the charging current beyond this point, that is, overcharging the cells, does no harm to the plates, but the energy represented by the current is wasted.

It is important not to increase the charging rate beyond that recommended by the manufacturer, otherwise the developed gas would not have time to unite with the positive and negative elements, and "gassing" would occur before the cells were fully charged. This would cause a waste in electric energy with possible injury to the cells.

34. Discharge.—When the charging current is discontinued and the external circuit of the cell completed by means of conducting-wires through some electrical device, then a current will flow in the *opposite* direction to that of the charging current, the pole that was connected to the positive pole of the primary battery now acting as a positive pole. If there should be any uncertainty as to which is the positive pole of the primary or storage-battery, then it can at once be determined by dipping the ends in water slightly acidulated, without letting the ends touch each other. The water will then be decomposed, and the increased amount of hydrogen gas developed at the negative pole will at once mark the latter as such. The positive and negative pole of a storage-battery should never be connected directly without some intervening resistance. The rate of discharge would otherwise be so heavy as to perhaps permanently injure the battery.

35. Testing of Accumulators.—In case the discharge current from an accumulator does not show the usual strength, one of the cells may have had its connections broken or a "buckling" may have occurred. A 2-volt incandescent lamp provided with conducting-wires may then in turn be connected to the terminals of each cell, and its condition ascertained by the glow of the lamp. Should no glow take place at one of the cells, then this one should be disconnected and the trouble ascertained. The total voltage of a battery may also be found by connecting a lamp to its main terminals possessing a voltage corresponding to that found by multiplying the total number of cells by 2.

36. Other Methods of Charging.—We have here mentioned only the one combination of placing the accumulator cells in series, as this is the simplest and quickest method to pursue. There may be conditions in which it is not possible to supply the high voltage required in the above example. In that case each cell may be charged separately or in combinations of 2 or 3, as the case may be. Or, if a charging current can be obtained of low voltage, but of high amperage, then all of the accumulator cells may be placed in parallel. Supposing the available amperage to be about 98, then it would take about the same time for charging as in the example cited above, when all the cells were in series, that is, in about 15 hours.

If a small dynamo is utilized for the purpose, then it is preferable to have one that is shunt-wound. This would prevent a reversal of its polarity by a possible slowing down in speed, in which case the current would return from the cells.

In Germany, Gulcher's *thermo-batteries* have been used with some success; they are durable and practical, though unable to give a high voltage and amperage, but they may, nevertheless, be useful for slowly charging storage-batteries. The largest single battery gives a current of 3 amperes with 5 volts pressure, and has an internal resistance of .65 ohm. Illuminating gas required for heating amounts to 6 cubic feet per hour. They have this advantage, that after lighting the gas-burners they are at once ready for use, require no attention, and may be left unused for months without loss in efficiency from deterioration.

37. Edison's Storage-Battery.—Lately, Edison has manufactured a storage-battery that is claimed to be far superior to any other existing at present. Of the advantages claimed, the following may be mentioned:

1. Absence of deterioration by work.
2. Large storage capacity per unit of mass.
3. Capacity of being rapidly charged and discharged.
4. Capacity of withstanding careless treatment.
5. Inexpensiveness.

The negative pole is attached to an element consisting of a finely divided compound of iron with an equal volume of graphite flakes, and the positive to one consisting of superoxid of nickel; it may therefore be called a nickel-iron cell. The electrolyte is potash, preferably a 20-per-cent. solution of potassium hydroxid, the freezing temperature of which is 20° below zero, Fahrenheit.

The initial voltage of discharge is 1.5 volts, while the mean voltage of full discharge is approximately 1.1 volts. The normal charging current rate is about 8.64 amperes per square foot. Charging and discharging rates are alike and may be 3½ or only 1 hour without any apparent detriment.

The positive and negative plates are mechanically alike, and consist of a thin sheet of steel in which rectangular holes are stamped. Each hole or opening is filled with a pocket or shallow box containing the active material; the box is perforated with numerous small holes to admit the electrolyte, but conceals entirely the contained active material from view. The cell may be fully discharged to the practical zero point of E. M. F. without detriment.

INCANDESCENT-LAMP CIRCUITS.

REGULATION OF CHARGING CURRENT.

38. Incandescent Lamps.—When connection can be had with an incandescent-lamp circuit, then this should always be utilized in charging accumulators, as it is not only much more convenient, but also more economical. As the amperage of this current would be very heavy for charging purposes, some resistance must be inserted in the circuit to reduce the current to its proper strength. For this purpose, metallic wires of varying lengths and diameters, constituting a so-called rheostat, may be used; but, ordinarily, it is more convenient to let the current pass through a certain number of incandescent lamps and in this manner provide the necessary current-strength.

A 16-candle-power incandescent lamp will pass a current of .5 ampere, and a 32-candlepower lamp, 1 ampere. By varying a number of these lamps in parallel, any required amperage may be obtained for charging purposes.

39. Connections.—Fig. 9 gives a diagrammatic view of how lamps and accumulators may be arranged. *a* and *b* are the main wires of the lamp circuit, and the arrows indicate the direction of the current through the lamps, switch, adapter, and

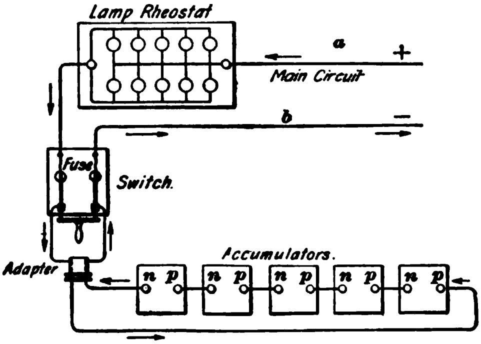

FIG. 9.

accumulators, back through conductor *b* into the main circuit. If 16-candlepower lamps are selected, then 10 of these will allow a current of 5 amperes to pass through the accumulators when the latter are arranged in series. The adapter is a plug-like appliance that may be inserted in a stationary socket and simultaneously connects the positive and negative wires of the accumulators to those of the main circuit. Two fuses are installed on the switch to insure against an excess of current, in which case they will burn out and break the circuit. The accumulator should first be, respectively, connected and disconnected before the switch is closed or opened. To give a detailed description of how to manage storage-batteries would be unnecessary, as the makers always supply this information. It should be added that, in general, there would be no necessity in using storage-batteries for operating the induction-coil when an incandescent-lamp circuit is installed in the operating-room, though some operators prefer even then to use storage-batteries, claiming to obtain better results. Ordinarily this would only be necessary if the coil had to be operated some distance away, where nothing but storage-batteries could be utilized.

40. Rheostat.—When using the incandescent-lamp current for operating the coil, some means must be had for regulating the current-strength similar to those used when charging storage-batteries. Preferably a variable resistance, made up of various lengths of iron or German silver wire, is then resorted to. These are combined either in a box or plate, over which a lever may be moved from one position into another so as to include shorter or greater lengths of these wires, thus interposing a lesser or greater resistance in the circuit. The reduction in pressure that the current suffers by passing through such resistances is rather wasteful when the pressure is that of the ordinary lamp circuit. All pressure not wanted in the coil is then wasted in the form of heat in the resistance-box. Resource is, therefore, often had to other means for bringing on the reduction in pressure without so much loss. As such, the motor-generator has been found very serviceable.

MOTOR-GENERATOR.

41. Construction.—The motor-generator is a combination of a motor and a dynamo in one frame with one set of field-magnets and two armatures. One of the latter is used as a motor, and sets the other armature in rotation, generating an E. M. F. of its own entirely independent of that in the main circuit and constituting part of a separate circuit. By selecting the proper size of wire and coils for the latter armature, it is possible to have a current of any desired pressure in the latter circuit. Thus the pressure of 100 volts in the lamp circuit may be changed in the generator to 10 volts with an efficiency of 80 to 90 per cent., consequently without the loss in heat, as in the rheostat. This is not the only advantage that a motor-generator may possess. It may also take an alternating current, which is not suitable for operating induction-coils, and change it into a direct current, the alternating current operating the motor-armature and the direct current emanating from the generator-armature.

GENERATORS.

42. Method of Operation.—In localities where no connection can be made with commercial lighting circuits, it may be possible to have a small independent generator of about ⅛ horsepower that may be operated by a water-motor, if a pressure of at least 10 pounds is present in the water-mains. For the utilization of the existing water-power, the Pelton water-wheel is superior to any other motor. If, for instance, a water pressure of about 40 pounds is available, which is usually the case, then a motor of 6 inches in diameter will furnish ½ horsepower. This motor may be situated in the cellar and be directly connected to a small dynamo from which the current may be sent through the induction-coil. Or, the dynamo may be used for charging a number of accumulators, which will be available at any time for operating the coil. In case water pressure should not be at hand, then a small gas or gasoline engine may be installed and its power utilized in running a ⅓-horsepower dynamo. The current furnished by the latter may be sent directly through the induction-coil, or, by winding the dynamo for low voltage, it may charge 4 or 5 storage-cells and these be used with the induction-coil. Dynamos and engines constructed with this purpose in view are in the market and may be had with the necessary directions for their installation.

STATIC MACHINES.

MAIN PRINCIPLES.

43. Comparison With Other Sources of E. M. F. The *static machine* has the advantage over the other sources of electrical energy that it contains the whole Roentgen ray apparatus, so to speak, combined in one unit. No primary or storage-batteries, nor transformer, induction-coil, or rheostat are required. All that is necessary is to set the machine in operation and a current of the required voltage and amperage will be delivered to the Roentgen ray tube. Considered from this standpoint alone, it is superior to all other means used for the same purpose. Nevertheless, these advantages, which seem to make it so greatly superior, are counterbalanced by certain drawbacks. The first of these is the price, which certainly is much higher than that of a coil able to produce the same results. Then the room required for its installation, and at times a certain dependency on the condition of the air, whether rich in humidity or not, must also be considered. The increase in price would not be against it in cases where the static currents are used for general therapeutic purposes, as its field of usefulness there is very great, while that of the induction-coil would be nil. On the other side, it has been claimed that the results obtained by the static machine in Roentgen ray work is inferior to that produced by means of the induction-coil, the current-strength of the latter being greater, and the time required for the production of good skiagraphs, as a consequence, materially reduced.

Weighing both sides of the question, we think it may safely be said, that when the intention is to have an apparatus for Roentgen ray work alone, an induction-coil is preferable. If the practitioner wishes also to use his apparatus in general electro-therapeutic work, then a static machine is preferable, and also in localities where it is difficult to obtain the commercial lighting current or to have necessary repairs attended to. The static machine is not liable to breakdowns and may run for years without any more attention than that of an occasional general dusting and cleaning.

44. Methods of Operation.—The machine may be operated by hand, or, if the power is to be supplied for long periods, by means of a small motor, either an electric, a hot-air, a gasoline engine, or with the small water-motor already mentioned, when the suitable water-power is at hand.

It will be out of place here to enter into an extended description of the static machine. Those that wish to study the principles on which the same is based may find these fully explained in *Electrostatics*. It may be said to consist of a series of stationary and revolving glass plates, the latter carrying positive and negative charges back and forth between the former, increasing the potential of the charges they deposit on them at the same time as free positive and negative charges are induced on the exterior metal conductors, called prime conductors, whence they may be delivered to the apparatus where they are to be utilized.

An increase of the number of plates will give a corresponding increase in the current-strength. Machines with glass plates too small in diameter or too few in number will not be satisfactory. They should at least contain 6 to 8 revolving plates 24 to 30 inches in diameter.

As it is of importance that the positive pole of the static machine be connected to the anode of the tube, one must be able to make a distinction between the two poles while observing the spark-discharge. On bringing the sliding rods so near together that the spark-gap is about 1 to 2 inches, it will be noticed that the stream appears white near the positive and violet at the negative pole. Should this test not seem decisive enough, then one of the prime conductors may be grounded by connecting it to a gas-pipe or water-pipe, when the spark-discharge will cease if the positive pole is grounded, but will be undisturbed when the negative pole is so connected. It should be remembered that while the prime conductors of a static machine may retain the same polarity for a long time, they are liable to change. Should such a change have occurred, it will at once be noticed by the peculiar glow of the tube. The green fluorescence will then appear, not in front of the anode, but will seem to emanate from its rear. The machine should be stopped at once and the tube connections reversed.

A static machine, to be at its best in skiagraphic work, requires tubes that are constructed especially for such machines.

VARIOUS METHODS FOR OPERATING THE ROENTGEN RAY TUBE.

45. There are three methods by which the charges from the static machine may be sent through the vacuum tube:

1. The direct method.
2. The oscillating-current method.
3. Direct method with current interrupters.

46. The Direct Method.—When this method is used, the conducting-wires from the Roentgen ray tube are connected directly to the prime conductors of the static machine and the spark-gap adjusted in conformity with the vacuum of the tube. Should the tube not start at once, it is only necessary to bring the prime conductors near enough together to allow a spark to pass, when the tube generally will begin to glow.

47. The Oscillating Current Method.—In this combination, shown in Fig. 10, the induced charges of two Leyden jars are used for operating the tube. For this purpose, two Leyden jars of the smallest size are used, one for each prime conductor and directly connected with them. In the binding-posts, connected with the outside coatings of the jars, the conductors from the tube are inserted. It must here be remembered that the outside coating of the jar connected with the positive prime conductor is not positive, but negative, and vice versa with the negative prime conductor.

Adjust the sparking-distance between the prime conductors from 3 to 6 inches, after the machine is in full action, until the position is found producing maximum radiance. Unless the jars are very small, there is always some danger of having the charges from the latter puncture the tubes.

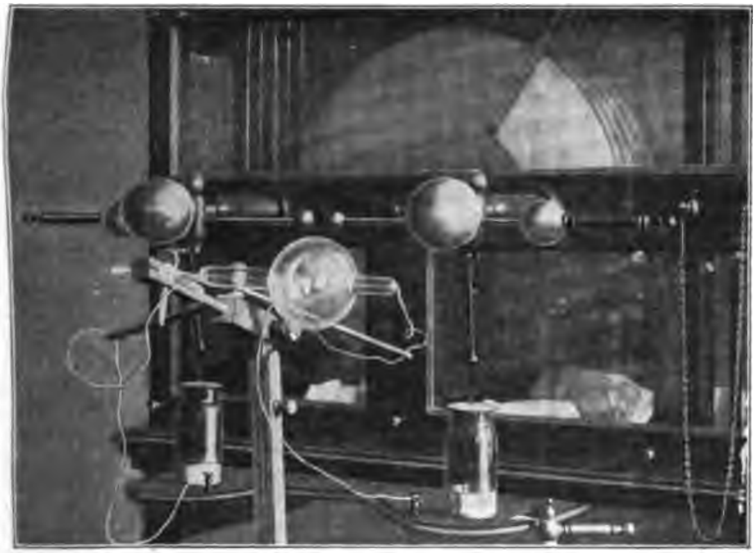

FIG. 10.

48. Direct Method With Current Interrupters. This is the method that is mostly used with static machines and that seems to give the best results. A little instrument, called an **interrupter,** is fastened to the insulating handle of each of the sliding rods, so that the little ball of the interrupter is in contact with that of the sliding rods, as seen in Fig. 11. The tube conducting-wires are inserted in little eyelets with which each of the interrupters is provided. The machine is set in action and the sliding rods of the prime conductors are separated so that no spark will pass between them. The length of the gaps between the interrupters and sliding rods should be adjusted until the tube gives maximum radiance.

It is usually found that it is sufficient to have a spark-gap only at one of these interrupters. Which one of these to select depends on the vacuum of the tube. If the vacuum is high, then the spark-gap at the negative interrupter seems to give the best results; if low, either the positive or negative, or both, may be used. Sometimes it may not be necessary to use either of the interrupters.

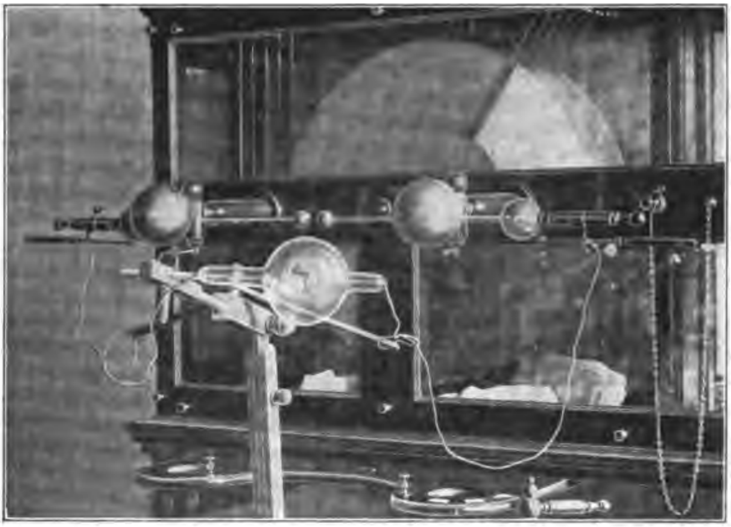

FIG. 11.

TRANSFORMERS.

THE INDUCTION-COIL.

49. Induction.—There are other means by which an E. M. F. may be produced than by the transformation of chemical into electrical energy. The most important of these is *induction*. Induction means the production of magnetization or electrification in a body without actual contact. We have seen that in order to make a current flow in a conductor it was necessary that the same was in actual contact with the source of electrical energy, for instance, a primary battery. When utilizing the phenomenon of induction, this is no longer necessary; we can then make a piece of iron magnetic by simply locating it in the neighborhood of a magnet or an active electric conductor. And, further, it is also possible to make a current flow in a conductor situated near another conductor carrying an electric current. *Why* these results are produced can here be explained only in general outlines. Full explanations will be found in *Magnetism and Electromagnetism.*

50. Inertia.—A current flowing along a conductor behaves as if in possession of *inertia.* By inertia is meant the tendency of a body to oppose motion while at rest, and while in motion to counteract a variation of same or a cessation altogether. We may find an analogy to this in the action of a grindstone, a fly-wheel, or any revolving body. To start a grindstone we must first overcome its inertia, its tendency to remain at rest. When in motion, and the intention is to stop it, its inertia will again assert itself, and it will tend to remain in motion; a counter-force must, therefore, be exerted to bring it to a standstill. Also, while in motion, it will oppose any variation in the speed of rotation.

51. Self-Induction.—An electric current will show similar characteristics. When a current is sent into a conductor there are forces active, tending to oppose the starting of the current. After the current is flowing, these same forces are counteracting any variation in current-strength, or its cessation. This reactive influence is called *self-induction,* and is one of the most important phenomena in electricity. At first glance it would seem to be a decided hindrance, but further study of the subject will show it to be of the most vital importance. The result of this self-induction is that when a current begins to flow, it cannot at once reach its full strength. After it has reached such strength, it will not at once submit to any change in it. And, further, when the current-supply is suddenly cut off, there comes an extra E. M. F. into play that tends to continue the current flow, entirely independent of the source of supply. This latter phase of self-induction is the only one used in Roentgen ray work.

52. Experiment Illustrating Self-Induction.—Let us now go a step further and imagine a conducting-wire to be divided in two parallel wires, entirely independent of each other, that is, insulated from each other along their whole length. We may still imagine these to be one wire, with this difference, that we are now able to send a current through one-half while the other is idle. Fig. 12 gives a diagrammatic view of the two conductors with their connections. The active conductor *b* is connected to two binding-posts b_1 and b_2. Conductor *d* connects the former to a key, or switch, *s*; the battery *B* is also connected to the latter and to the binding-post b_2 by conductors *e* and *f*, respectively. The idle conductor *a* is connected to two other binding-posts a_1 and a_2, and the latter is brought in communication with a galvanometer *G* by wires *c*, *c*.

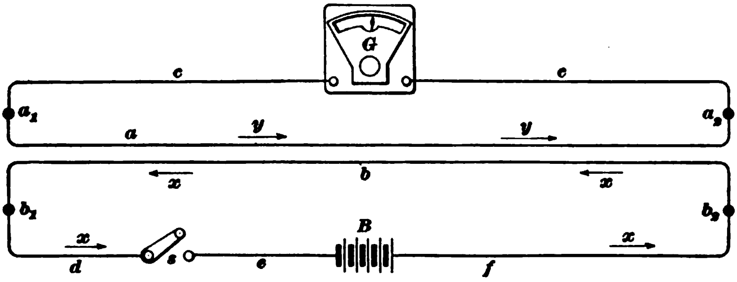

FIG. 12.

In order to fully understand the following experiment, let it again be emphasized that the wires *a*, *b* could be one wire, if it were possible to let one part of the wire be idle while the other transmits an electric current. The phenomenon of self-induction takes place just as well with one as with the two wires into which it is here divided.

When the key *s* is closed, a current will flow through the conductor *b* in the direction of arrows *x*, *x*. A self-induction will at once arise and tend to send a current in an opposite direction, thus weakening the closing current and delaying it in reaching its full strength. Simultaneously with the self-induction produced in *b* a similar induction will be called in play in conductor *a* in the direction of arrows *y*, without any actual contact between the two conductors. But there is this vital difference between the two phenomena, that while that in *b* must act against the pressure or, E. M. F., of a current, that in *a* has an entirely open field and can at once send a current through the whole circuit *a c*, signifying its presence by the motion of the pointer in galvanometer *G* toward the right.

As soon as the current in *b* has reached its full strength, then all reactive influences will cease both in this conductor and its mate. At any moment when any *increase* in current-strength takes place, the same results will follow, and at once a current will flow in conductor *a* in the same direction as arrows *y*.

53. Extra Current.—The most important part of this experiment is the result following the *opening* of key *s*. The self-induction of the circuit *b* will, then, again assert itself at once and will now tend to *maintain* the flow, producing what is called an *extra current*. While the key *s* is in the act of being opened, and thus breaking the continuity of the circuit, the only possibility for the current to continue its flow is to complete its circuit by jumping across the air-space in key *s*, which it will do by means of a spark. Again, a self-induction has asserted itself in the other circuit *a*, and here, also, in the same direction as that in *b*, that is, in the direction of the arrows *x*, consequently, in the *opposite* direction to the previously induced current, which was indicated by the arrows *y*. The pointer in the galvanometer will now go to the left.

54. Primary and Secondary Currents.—To repeat: on closing the key *s*, an E. M. F. will be produced and a current will flow in circuit *a* in the *opposite* direction to that of circuit *b*. On opening the key *s* an E. M. F. will be produced and a current will flow in the circuit *a* in the *same* direction as that in circuit *b*. The circuit *b* in which the inducing, or primary, current flows is called the *primary* circuit, while the circuit *a* conducting the induced, or secondary, current is called the *secondary* circuit.

55. Condenser.—It is seen, then, that the circuit *a* is active *only* when a change takes place in circuit *b*, and it will be understood that the more violent these changes are, the more violent will be the results in circuit *a*. To accomplish a sudden *starting* of a current in conductor *b* will not be possible, as the self-induction will always prevent it. The only means left is, therefore, to make the break at *s* as sudden as possible, and here some difficulties have to be overcome, that is, sparking at the contact points of key *s*. Fortunately, means have been found to overcome this by the appliance *c*, shown in Fig. 13, that consists of a number of tin-foil sheets, insulated from one another and alternately connected with the two conductors *g* and *h*. The latter are in electric connection with the lever and contact plate, respectively, of the key *s*. This combination is called a *condenser*, and is, in reality, two separate conductors of very large area, insulated from each other, but capable of exerting a mutual inductive influence on each other. The effect produced by inserting this condenser in parallel with the key *s* is, that when the latter is opened, the *extra* current from conductor *d* will, by preference, pass down along wire *g* into the condenser *c* instead of sparking across the air-gap in key *s*. By selecting a condenser of the right capacity, it is possible to make the current interruption practically instantaneous and to produce a maximum effect of self-induction in the circuit.

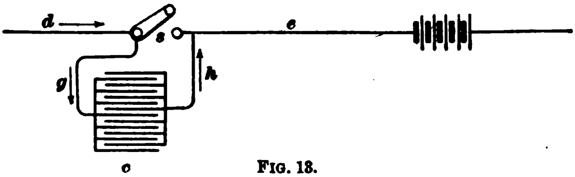

FIG. 13.

56. Principles of the Induction-Coil.—The experiment, previously described, elucidates the main principle on which the induction-coil is based, and it remains only to show the practical application of it.

The first requirement will be to shape the wire *b*, Fig. 12, into the form of a helix, partly because its various coils and layers have a stronger mutual inductive influence on one another, and also to economize space, as one single straight wire would show very feeble inductive effects when transmitting a current of ordinary strength.

In Fig. 14, the conductor *b* of Fig. 12 has been transformed into the coil *P*, here called a *primary* coil, because transmitting the primary or inducing current from the battery. Instead of the key *s* we have now an automatic interrupter to be described further on. *C* is a core of soft iron usually made up of a number of soft, thin iron wires. The core is not made solid but subdivided, so as to prevent the induction from causing local currents to flow in the core, which would tend to heat it and also to cause a reaction on the current in the primary coil. The purpose of the core is to increase the self-induction of the coil. An active electric conductor shows magnetic effects in its immediate surroundings. These will be magnified when, as in this instance, numerous layers of wires surround an iron core; the latter will have magnetism induced in it and show very strong magnetic attraction. *R* is the condenser; it consists of insulated leaves *a* and *b* united, respectively, to the conductors a_2 and b_2 that are connected to the ends of the coil *P*.

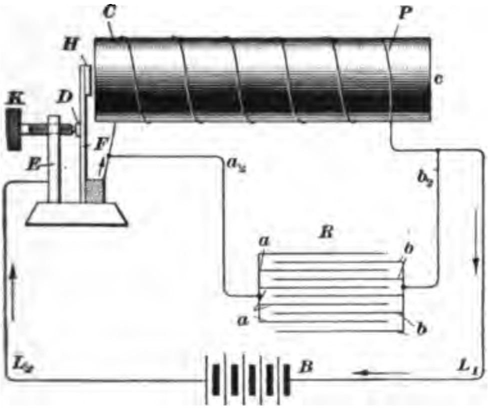

FIG. 14.

57. Action of an Induction-Coil.—The current from the battery passes through conductor L_2 into the post *E*, from here through the screw *K* to the contact *D* on armature *H* into the coil *P*. The core will be magnetized and attract the armature *H*. The continuity of the circuit has thus been broken at *D*, and a current can no longer pass across the air-gap between *D* and the screw *K*. As the coil is now cut off from all connection with the battery, the self-induction of the coil will begin to assert itself and send an *extra current* through the coil and conductor b_2 into the condenser. When this current has ceased, the magnetism of core *C* will, also, cease and the armature, or hammer, *H* will return to its original position, again letting the contact *D* come in touch with screw *K*. The current then continues its flow as before, and with the same results.

The other conductor *a*, as shown in Fig. 12, is also made into a coil and usually wound around the outside of the primary coil. It constitutes, then, the *secondary* coil of an induction-coil, and the current that periodically flows through it is the *secondary* current.

In Fig. 15, *S* represents a secondary coil wound on the outside of the primary coil *P*; both coils are supported by a spool *O* of insulating material surrounding the iron core *C* laid in its interior. A switch *W* connects the post *E* with the terminal P_1, and the terminals P_1 and P_2 are joined to the battery *B* by means of L_1 and L_2. The terminals S_1 and S_2 of the secondary coil are not, for the present, in electrical connection with each other; the secondary circuit is, therefore, open.

58. Importance of Quick Interruptions.—From the fact that a current in the secondary coil flows only when a change takes place in the primary coil, it follows, at once, that if any great activity is to be produced in the former coil, these variations must be as numerous and as great as possible; therefore, the importance of having a suitable and well-constructed interrupter, or vibrator, for which reason we will further on explain this device in detail.

59. Nature of Secondary Current.—The next question that will suggest itself is this: "How can the current from the secondary coil be used for the lighting of a Roentgen ray tube, when the latter demands a direct current." As already explained, the self-induction caused by the *breaking* or opening of a circuit is many times larger than that resulting from the *closing* or completing of a circuit. Consequently, the former will be able to pass a current through a resistance that the latter will be powerless to penetrate. We can therefore understand that if we have a spark-gap of, say, 10 inches between the terminals of the secondary coil, the breaking current might be able to jump across it, while the closing current will be unable to do so, because its E. M. F. is perhaps unable to bridge a gap longer than 6 inches. As a result of this, sparks will only pass across belonging to the breaking currents, and as all these go in the same direction, it follows that the current will be *unidirectional* and *intermittent*.

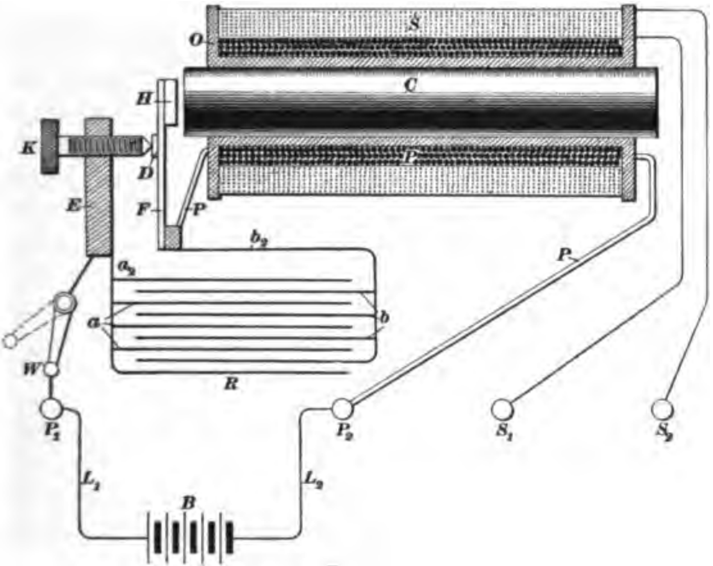

FIG. 15.

60. Difference Between E. M. F.'s in Primary and Secondary Coils.—Another point that may offer some difficulty in understanding is the relation between the pressures in the primary and secondary coils. If the coils P and S, Fig. 15, were made of wire of the same diameter and length, then the pressure and strength of the currents in both coils would practically be the same, not considering a certain loss depending on the efficiency of the combination. The more windings or convolutions that the secondary coil contains, the more will it be exposed to the effects of the inductive influences of the primary coil. The E. M. F. developed in the secondary coil would, up to a certain limit, increase in direct proportion to the increased number of windings that it may contain in the same space on the bobbin. But as the total power in watts developed in the secondary coil cannot be increased, it follows, as a consequence, that an increase in pressure can only be bought at the expense of a decrease in current-strength. For instance, let it be supposed that a power of 50 watts is developed in the secondary coil. This may be done by a current of

10 volts and 5.0 amperes.
100 volts and .5 ampere.
1,000 volts and .05 ampere.
10,000 volts and .005 ampere.

Thus, the pressure in the secondary may be increased to from 200,000 to 300,000 volts, but with a corresponding decrease in amperage. It is well to bear in mind, particularly in Roentgen ray work, that coils having a large sparking distance cannot give a strong current, unless the primary is traversed by a current much larger than that ordinarily used for Roentgen ray coils, and the secondary coil is made of a correspondingly heavier wire.

Increasing the diameter and decreasing the length of the wire in the secondary coil will decrease its voltage and increase its amperage, so that it is not only possible to increase the pressure of the current in the secondary coil over that in the primary, but also to decrease the pressure in the secondary coil with a corresponding increase in its current-strength.

61. Comparisons Between Various Coils. — When coils are compared it is customary to simply mention their sparking distance, say 8, 10, 12 inches, or whatever the same may be. This gives no idea whatever of the real power of the coil, any more than when speaking of a waterfall we would say, it is about 50 feet high. How *much* water really flows per minute would be left to the imagination, and an estimate of its horsepower would be simply impossible. The same argument applies to the rating of induction-coils. It is necessary to know not only the *pressure* indicated by the sparking-distance, but also the current *volume.* Two coils may be made to give exactly the same length of sparks, but of very different nature. In one case, it may be thick and intensely white, in the other, thin and bluish. The former coil is the more powerful of the two and the more expensive to build. To send this increased current-strength through the coil, it must be made of heavier wire, both in the primary and secondary coils, with an increased expense both in copper and labor.

As the current in the secondary is not continuous, but interrupted, the current-strength will depend on the volume of current sent through the spark-gap at each interruption. Here, again, a deception is possible. If two coils send sparks of the same volume over the same air-gap, they would be identical, provided this were done at similar intervals. But if one does this at double the number of interruptions per second, then, evidently, double the current volume will cross the air-gap. Some coils can be made to show a high efficiency by slowing down the vibrator. But as the power of the coil, or the number of watts, depends on the product of amperes into volts, it is seen how important it is to ascertain the volume of the current, as the number of watts consumed determines not alone the penetrative power of the rays, but also their rate of action; as, for instance, when used for making a skiagraph. It will also be seen that high pressure, with the resulting high penetration of the rays, is not the only consideration to have in view, in particular if it is bought at the expense of the current volume.

INTERRUPTERS.

62. Simple Spring Interrupter.—The action of the ordinary spring interrupter has already been explained. Its mechanical construction and the various improvements it has undergone since the induction-coil has been utilized for Roentgen ray work will now be described more fully. Fig. 16

represents the form commonly used on coils of moderate size. *H* is the hammer, or armature, on spring *F* facing the platinum point *D* on the end of screw *K*. The latter adjusts the sparking-distance, or angular motion of the hammer. Further means for changing the rate of vibrations is found in the additional screw K_1 near the base, which can submit the spring to an additional tension.

63. Improved Spring Interrupter.—It has been stated previously that it is of the utmost importance to have the current interrupted as quickly as possible. This the vibrator in Fig. 16 is not able to do; it has the two drawbacks of devoting too much time to the act of interruption and too little to the period of contact. It is not enough to give a quick interruption; the current must also be given sufficient time to reach its rate of maximum flow before being interrupted. Otherwise the full strength of the supply current is not utilized. Fig. 17 shows an improvement in the interrupter in which the attempt has been made to attain these advantages. Similar parts having been lettered the same as in Fig. 16, it will be necessary only to describe the additional parts. We notice, then, that the spring *F*, Fig. 16, has been subdivided into two springs, F_1 and F_2. This makes it possible to let the spring F_2 with the armature *H* be in motion while the other spring F_1 with the platinum contact *D* is at rest. The hammer *H* possesses a certain amount of inertia, consequently it is not able to at once attain its maximum speed. In the arrangement shown in Fig. 16, it starts from a position of rest to at once break contact with screw *K*; this interruption takes place, therefore, while it moves at a minimum speed. Again, as a result of the long time spent in interrupting, it can spare no time to leave the parts in

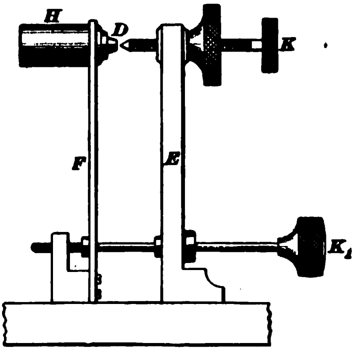

Fig. 16.

contact. In Fig. 17, the hammer *H* can move through a certain variable distance and attain its maximum velocity before a break takes place. This is effected by means of the bracket *I* and adjustable screw *G*, which will not strike the contact spring F_1 before spring F_2 has moved far enough to bring the screw *G* in contact with the insulating plate *g*, when both springs move in unison. This is not all; when the springs return together again, the platinum contact *D* of spring F_1 strikes the screw *K* while both springs are moving at a maximum speed. The latter spring is, therefore, brought to a sudden stop and remains at rest, completing the circuit, while spring F_2 is still moving to the left. When its momentum has been overcome by the new attraction of the core *C*, Fig. 15, it begins again its travel to the right, and the interruptions are repeated.

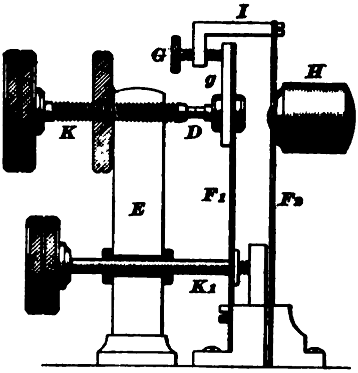

FIG. 17.

It is claimed that this interrupter increases the efficiency of a coil very materially besides preventing sparking and sticking at the contact points. From its increased contact period, whereby the current gets time to reach its maximum strength, a reduced battery power is required.

Most modern spring interrupters are based on the above construction, some small variations being made in allowing the hammer its extra freedom in swinging to and fro. Usually a stem is inserted in the upper part of the armature *H* on which an adjustable counterweight is placed. By its means quite a variation in rate of interruptions may be obtained.

64. Independent Spring Interrupter.—To let the interrupter be operated by the core of the induction-coil is sometimes inconvenient, as variations of the current-strength through the same also influences the rate of interruptions.

This, then, requires a new adjustment of the interrupter to comply with the new conditions. Usually it is desirable to let the rate of interruptions be constant and to adjust the current-strength independently of this. For these reasons it is now customary to let the interrupter be operated in an independent circuit, either in parallel with the main circuit or supplied by a separate cell. A combination of this nature is shown in Fig. 18. *S* is a small coil with a core *C* acting on the armature *H* that is supported by the main spring F_1. The screw *K* projects through an aperture in the same and strikes against the platinum contact D_1 on spring F_2. When the armature *H* moves to the left, it reaches the spring F_2, and then both move together in the manner and with the effect already explained. The supplementary coil is supplied with its current through the screw K_1 and contact D_2, both insulated from the main circuit. The rod *L*, with counterweight L_1, makes it possible to change the rate of vibrations.

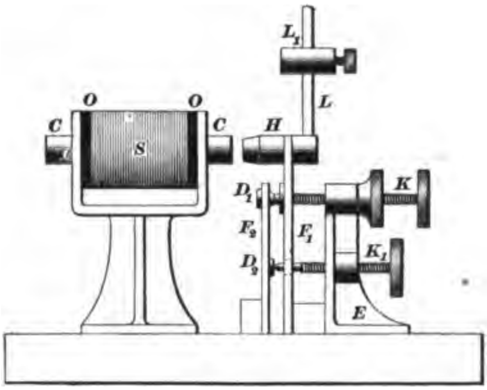

FIG. 18.

65. Edison's Air-Break-Wheel Apparatus.—Instead of the spring interrupter, various others, mechanically operated, are in use. Among these may be mentioned Edison's air-break-wheel apparatus, illustrated in Fig. 19. It consists, in the main, of two metal wheels having serrated edges against which two brushes rest. The wheels being set in rapid rotation by means of an electric motor, and a current being sent through the brushes, an intermittent current will be produced suitable for the operation of the coil. In order to suppress any sparking effects at the brushes, the latter are constantly exposed to an air-blast from two nozzles connecting with a small pressure blower, also operated by the motor. The apparatus may be connected to a 110-volt direct-current circuit, and a suitable rheostat provided to control the current passing through the coil.

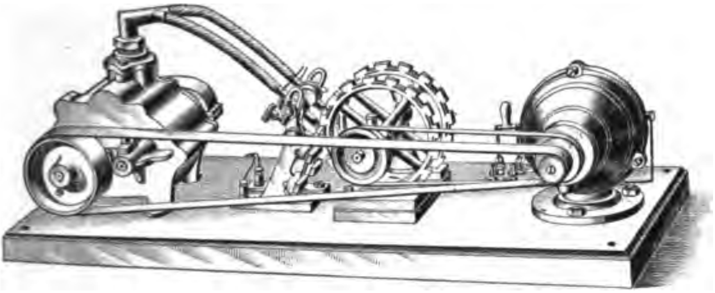

FIG. 19.

66. Mercury Interrupters.—As some inconvenience may result from the irregular wear of the platinum contact points in the spring interrupters, it has been proposed to replace them by a cup of mercury into which a contact rod may dip and be set in rapid reciprocation. The rod may either be operated by a small coil or receive its motion from the crank of a small electric motor. The mercury is, as a rule, covered with a layer of petroleum or alcohol, about 1 inch deep, or even water, to prevent sparking when the rod leaves the mercury.

A recent form of interrupter that has been quite successful is the **mercury turbine interrupter.** Its leading feature may be understood if we imagine the brush in the Edison air-break-wheel interrupter (see Art. 65) replaced by a stream of mercury. These interrupters have a vertical shaft set in rotation by a little electric motor. The lower end of the shaft consists of a tube having two extensions, one, with a scoop-like opening dipping into mercury, forces a current of the latter upwards and through the other extension in a horizontal direction toward a metal ring surrounding the tube. This ring has perforations that allow the mercury stream, in certain positions, to pass through without touching the metallic part. If, now, the ring is connected with the induction-coil and the mercury with the source of electric energy, it will be understood that, whenever the mercury strikes the solid part of the ring, a current is sent through the circuit, which again is interrupted whenever the mercury passes through one of the perforations.

In another variation, the mercury spout is stationary and the ring revolves. None of the parts having reciprocating motions, it is possible to let the rate of interruption be as high as 100 per second. The contact is made under alcohol, oil, or water. These interrupters are suitable for current-strengths varying between wide limits, and are practically noiseless.

A simplified form of a rotary mercury interrupter is one designed by Mackenzie Davidson. It consists of a small electric motor that sets a thin spindle in rapid rotation. The end of the spindle is provided with a small vane that dips in mercury once during each revolution. The motor stands in an inclined position on top of a wooden box so as to allow the vane to dip into a mercury cup situated inside the box.

67. The Wehnelt Interrupter.—Still another extensively used interrupter is that constructed by *Wehnelt*, Germany. This is based on the electrolytic action of the current and is capable of a very high rate of interruptions, in fact, as many as 1,000 to 100,000 per minute. The *Wehnelt interrupter*, as originally constructed, is rarely used now, but mostly some of its numerous variations.

The original Wehnelt interrupter, as seen in Fig. 20, has, in common with the *Caldwell* interrupter to be described further on, the tendency to concentrate the action of the current on a very small area. Here it is a short piece of platinum wire, about $\frac{1}{32}$ inch thick, which projects for a distance of $\frac{1}{8}$ inch beyond the end of the glass tube *b*, into the end of which it is fused. A conductor *c* is inserted in this tube and brought in electric communication with wire *a* by means of a column of mercury that is poured into the tube. This constitutes the *anode.* A lead plate *e* in contact with the negative conductor *d* serves as the *cathode.* The beaker *A* is filled with an electrolyte consisting of 1 part of sulfuric acid to 3 or 10 parts of water. When a current of sufficient voltage, from about 20 to 110 volts, is sent through the liquid, a light of violet-blue color appears around the platinum point and a periodic accumulation of gas, with a resulting interruption of the current takes place. The strength of the current through the interrupter may be varied by mixing more or less water in the electrolyte. Decreasing the percentage of sulfuric acid will increase the resistance. Or it may be regulated by the addition of a simple water rheostat *W* in the circuit, as shown in Fig. 21, and partly by the length of platinum wire projecting beyond the end of the glass tube. The frequency of the interrupter can conveniently be regulated by inserting a variable

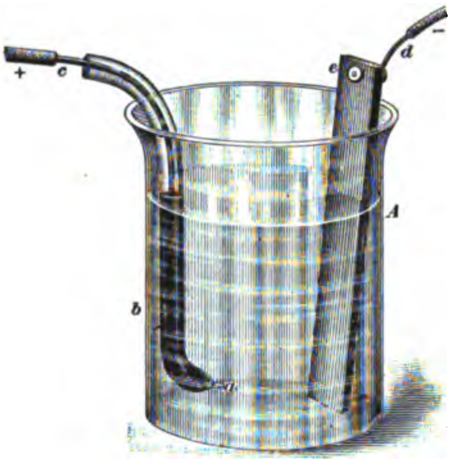

Fig. 20.

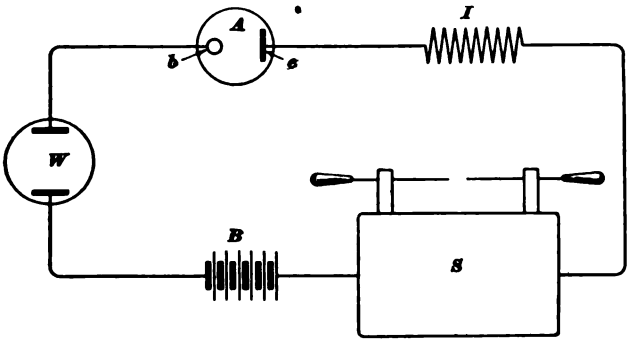

Fig. 21.

self-induction *I* in the circuit. This may consist of a coil of about 100 turns of No. 18 wire into which is placed a core, 10 inches long and about 1 inch in diameter, made of thin iron wires. A partial withdrawal of the core will increase the rate of interruptions. The latter may also be influenced by the active length of the platinum wire, a shortening increasing the frequency. Sometimes the self-induction of the primary coil alone may be sufficient. The general arrangement, when using a direct current from an accumulator, may be seen from Fig. 21, in which *B* is the accumulator, *S* the induction-coil, and *A* the Wehnelt interrupter with glass tube *b* and lead plate *e*.

The Wehnelt interrupter may also be used with the commercial alternating circuit, in which case the inductive resistance-coil is omitted. The rate of interruptions is now fixed, depending on the number of alternations in the circuit, which usually amount to from 120 to 160 per second. The current-strength can now be regulated only by changing the active length of the platinum wire, by the density of the electrolyte, or by a rheostat.

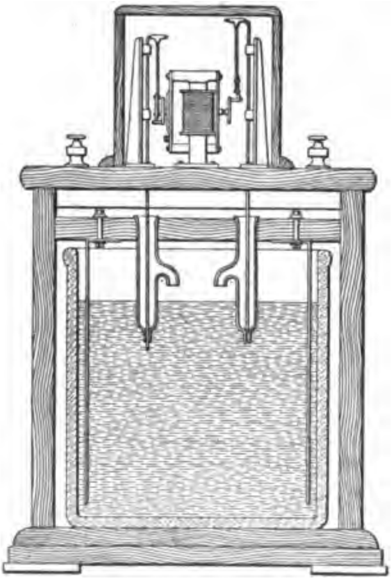

Fig. 22.

68. The Heinze Break.—In some of the electrolytic interrupters the platinum wires are made movable in their glass tubes and given a reciprocating motion. An example of this class is the *Heinze break* shown in Fig. 22. Here the glass vessel is placed in a wooden box on top of which is a small electric motor. The latter is mechanically connected with two platinum wires, which it alternately projects into the electrolyte. The cathodes are, as before, lead plates. It is claimed that this interrupter can stand rough usage and will give a steady light.

69. The Caldwell Interrupter.—Though the Caldwell instrument is usually classed among the electrolytic interrupters, its action is not exactly that of Wehnelt's, but it is more nearly based on the heating effect of the current on a small column of water of high resistance, periodically heating the same to the point of boiling, when the circuit is momentarily broken. Fig. 23 illustrates one of these interrupters with some additions by *Swinton*. *A* and *B* are the two lead electrolytes provided with the binding-posts *E* and *F* suspended from an ebonite cover *G* and projecting into the glass beaker *D*. The electrode *A* is insulated from *B* by a glass tube *C* provided with a small aperture *g*, about $\frac{1}{8}$ inch in diameter, through which a pointed glass rod *c* projects. This glass rod is inserted in a threaded metal sleeve *f*, and engages with a nut *e* by means of which the rod may be raised or lowered, and thus vary the available part of the aperture *g* and at the same time the current-strength. The electrolyte consists of dilute sulfuric acid, about 1 part of acid to 10 or 20 parts of water. Care must be had not to have the beaker too full, as it is the tendency of the liquid in the tube *C* to

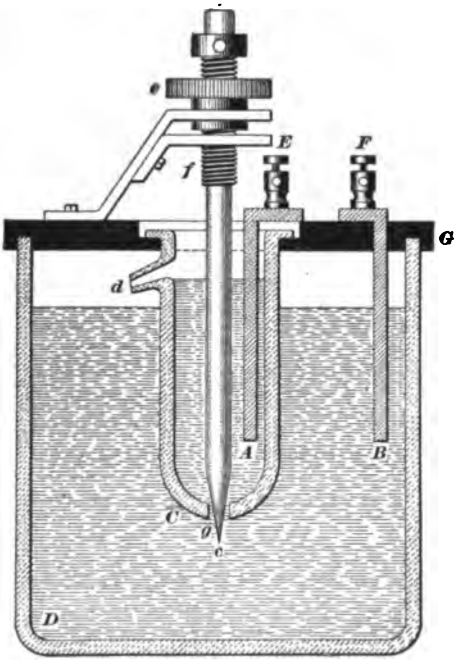

FIG. 23.

raise above that in the beaker. This difference should not be more than enough to allow the overflow to *drip* from the spout *d*; if a small stream should flow from the spout, a short-circuit will occur between the two liquids. The size of the electrodes is the same; it therefore makes no difference in which direction the current flows through the liquid.

When the Wehnelt or Caldwell interrupter is used in connection with an induction-coil, then the condenser and spring interrupter are put out of action and the interrupter is placed in series with and between the coil and the battery. It is claimed that this interrupter greatly enlarges the efficiency of an induction-coil, giving a current of high amperage that is able to produce Roentgen rays of great penetration. At the same time, when using the Wehnelt or Caldwell interrupters, the Roentgen ray tube is liable to overheating, and may be destroyed within a few seconds if it is not constantly watched and the current shut off in time.

70. Induction-Coil Connections.—Having considered in detail the functions of the induction-coil with its various appurtenances, it remains to consider them installed with their correct connections. This subject can very properly be treated briefly, as the variations are numerous, and the operator would rarely feel himself competent to personally undertake the installation of any one of the large modern induction-coils, in particular if its electrical energy should be derived from one of the lighting circuits.

For the sake of completeness, we give in Fig. 24 an example of a coil made by one of the leading firms. It is constructed for connection with a 110-volt circuit and has, for purposes of regulation of current-strength, a rheostat installed in its base, the handle of which is visible. We also notice the interrupter and the switch for adjusting the condenser, inserted in the base. On top of the coil the discharge rods are found, which may be moved simultaneously by turning the milled head until the desired spark-gap has been found. In addition to this, there is also a series spark-gap that acts as a safeguard against an alternating discharge in the main spark-gap by preventing the closing current from bridging across the latter. There is also an interlocking switch, whereby it is impossible to send the main current through the coil before the interrupter is in operation. This is of importance, as, when using a storage-battery, it would be possible to send a current of 20 amperes or more through the coil, which would be more than an ordinary coil could safely stand and might be the cause of ruining it.

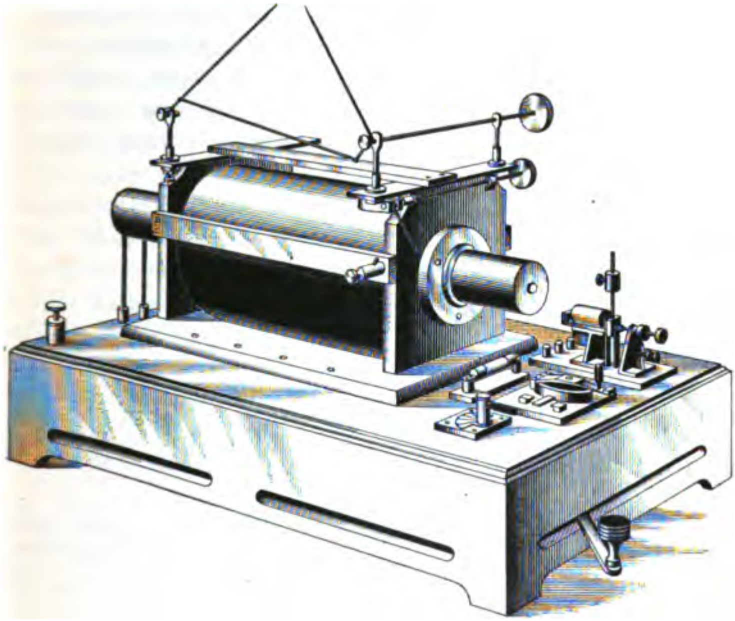

FIG. 24.

As a coil of this size is a producer of a very high E. M. F. in connection with a rather heavy current, it is important to bear in mind that it is a dangerous thing to handle the coil while it is in action. In particular does this refer to the interrupter, which should not be touched while the main current is on.

It is advisable to have an ammeter in the coil circuit, as an indicator of the current-strength used on different occasions and to guide one when similar experiments must be repeated. A voltmeter is also of advantage, and is indispensable when storage-batteries supply the current, in order to ascertain the existing pressure of the same and to prevent the discharge from going too far with the resulting buckling and sulfating of the plates.

It should be the aim to have the switches needed for manipulation of the coil within easy reach, and a provision should also be made for an extra lamp, or light, that can quickly be turned on when needed. This would be the case when the work is going on in a darkened room, in order to better observe the action of the tube.

When the Edison air-break-wheel or similar interrupters are used, it is customary to locate them in places where their noise will not influence the patient too much. Some manipulators have a special closet for this purpose, the door of which may be closed after it is in proper working condition. The coil may then be on a table near this closet with a rheostat on the wall above same. A switch on the table is within easy reach whenever the current is to be shut off, either for the purpose of changing the tube or for effecting some additional adjustment.

What was said in Art. 44 about polarity applies also here as regards the appearance of the spark and the tube. To ground the poles, for the purpose of testing polarity, is not practicable with coils. When connections have once been correctly made, they should be properly marked to prevent future mistakes.

71. Transportable Roentgen Ray Apparatus. Whenever a patient is in a condition such that his transportation to the Roentgen ray laboratory is impossible, then it is of importance to have apparatus that will allow its transportation without too much inconvenience. If an induction-coil is used, the main difficulty is to find a source of electrical supply. This will be relatively easy if access may be had to the commercial lighting circuit. Mostly, however, this will not be the case, and then recourse must be had to storage batteries. The size of the latter will depend on the coil and the length of exposure.

If a large size is necessary, it is of advantage to divide it in smaller units, placed in independent boxes, that later on may be electrically connected, thus making their transportation more convenient. The coil itself, with the interrupter, rheostat, fluoroscope, plates, etc., is usually housed in a separate box, provided with handles and rollers.

If a medium size Wimshurst or Toepler machine is at hand, then the operator is more independent, as it may be utilized anywhere, entirely independent of any lighting circuit or storage batteries. The motive power may be supplied by hand, as the power required is small and of short duration.

THE TESLA COIL.

72. This coil was formerly considered essential for success in skiagraphy, but it has since gradually lost its superior position. This is caused, mostly, by its additional complication over that of the ordinary induction-coil and by the necessity of having the supplementary coil immersed in an oil bath. It is true that the coil is able to produce currents of a very high E. M. F. and to require very short exposures for skiagraphs, but it has been found that the ordinary induction-coil, in its improved forms, is able to give all the E. M. F. and current that the Roentgen ray tube, in its present form, is able to stand.

In the Tesla coil, an alternating current is sent through a primary coil that acts inductively on a secondary coil, as in other induction-coils; but instead of using the secondary current directly for operating the Roentgen ray tube, it is sent into a condenser. By this means the current is set into very rapid oscillation, about ten millions per second, and is then sent through the primary of a supplementary induction-coil, where it again induces a secondary current of a still higher potential in another secondary coil. Both of the latter coils have very few windings and are inserted in oil to insure perfect insulation.

THE ROENTGEN RAY TUBE.

NATURE OF THE ROENTGEN RAYS.

73. Their Relation to Other Rays.—The whole subject of Roentgen rays is one on which many conflicting opinions exist. To say positively what the Roentgen ray really is, whether light, an electric current, or a stream of molecules, all of which propositions have been held, seemed at first very difficult. Nevertheless, the field has been made somewhat clearer since Roentgen made his first exhibition in 1895, when he expressed the idea that Roentgen rays might be longitudinal vibrations of the ether. This explanation of the problem has been abandoned, and there is now little doubt but that the Roentgen rays belong to the light phenomena and occupy a place in the spectrum beyond the invisible *ultra-violet* light in a class that may be called *ultra ultra-violet.* They would seem to be, therefore, transverse ether waves.

In Fig. 25 a diagram is given indicating the position of the optical, chemically active, heat rays, and electromagnetic ether waves. On the extreme right we find the Roentgen rays. The length of the waves are given in microns. One *micron* is one-millionth meter or .001 millimeter. The ultra-violet and the Roentgen rays have these properties in common, that they produce fluorescent and chemical effects in various substances, and that they are able to discharge electrically charged bodies.

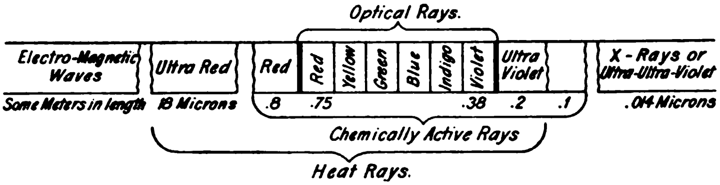

FIG. 25.

74. Typical Roentgen Ray Tube.—The apparatus commonly used for the production of Roentgen rays is so universally known that little need be said here. Fig. 26 shows the fundamental form, in which the cathode is on the left, consisting of a concave circular reflector of aluminum, and the anode on the right, made in the form of a smooth polished disk of platinum. At either end are terminals that may be connected with the negative and positive conductors of the induction-coil. The usual description of Crookes tubes and the effects obtainable at various degrees of exhaustion will be omitted, as it is more of historical interest, and may be found elsewhere.

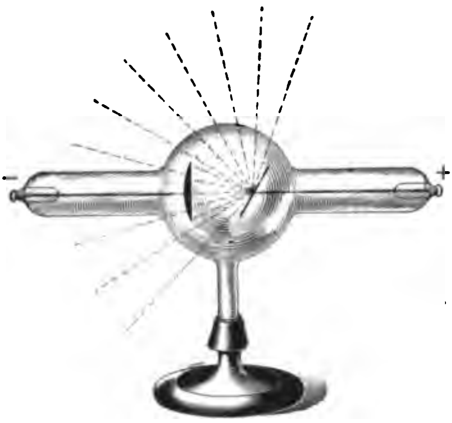

FIG. 26.

75. The Vacuum of Roentgen Ray Tubes. — The main point aimed at in the production of good Roentgen ray tubes is the attainment of a suitable vacuum. The whole manipulation necessary for this result is more or less empirical, and the products very variable in their qualities, no two tubes being exactly alike. When considering that the pressure in the tube has been reduced to from 1 to 2 millionths of the atmospheric pressure, and that little variation is allowed, it will be understood that their production is not an easy matter, if uniformity is required.

76. Radiant Matter.—When the pressure in a tube has been decreased to this extent, the remaining gas is said to be in a "radiant state." This means that so few molecules remain that they are able to travel in space for relatively long distances without colliding with one another. They then constitute "radiant matter."

77. Cathode Rays.—We may then presume that the molecules receive a negative charge from the cathode and are forcibly repelled from the same, attaining a velocity of about 62,000 miles per second. They will travel in paths at right angles to the surface from which they receive their negative charges, and it is, therefore, possible to predetermine the direction in which they will proceed. This collection of repelled molecules is called *cathode rays*. On the direction of these rays the anode has no influence and may be situated anywhere in the tube.

78. Transformation of Cathode Rays.—By giving the cathode the curved form indicated in the figure, it is possible to let the molecules radiate toward a common center and there concentrate the resulting effects. It is now assumed that the molecules, or atoms, when they strike the anode, are set in rapid vibrations. Their *mechanical* vibration may be transformed into ordinary light, but in this case it is assumed that their electrical charges are set in vibration, that it therefore is a question of *electrical* vibrations and that these vibrations of electrical charges may produce the Roentgen rays. In other words, it is a kind of electrical surging and splashing effect that takes place.

79. Function of the Focusing Point.—It must not be assumed that the Roentgen rays are *reflected* from this focusing point of the cathode rays in which the transformation takes place. Rather must this point be considered as a source of light from which the rays radiate in all directions. If the anode were perfectly plain and highly polished, the rays would radiate even in a direction nearly parallel with the surface, but as these conditions are not fulfilled, they will decrease in strength as they approach an angle of about 2° to 3° with the plane of the anode.

That place on the anode where the cathode rays meet should be a point, but in reality it is a circle. Its diameter should not exceed .04 to .08 inch if skiagraphs with clear outlines are desired. From observations made by Dr. Gocht, Berlin, it seems that this little circle is not the real source of the Roentgen rays, but rather a ring-like surface immediately adjoining it.

It was found that a number of tubes in which the anodes had been punctured by the effects of heat showed an undiminished production of Roentgen rays, notwithstanding the fact that a large portion of the rays would seem to pass entirely through the anode.

In the tube, as originally constructed, the cathode rays were allowed to strike the walls of the tube. If, under these circumstances, the rays were focused to a common point, then the results were that the heat resulting from the atomic bombardment was enough to melt and puncture the glass. If, on the other hand, they were dispersed over a larger area, then the Roentgen rays had to pass through a larger surface of glass with a greater loss from absorption by the latter.

80. Anticathode.—In some tubes, the anode does not act as the focusing point of the cathode rays, but is placed somewhere else in the tube. It is then replaced by a so-called *anticathode*, which should be in electrical connection with the anode. Fig. 27 gives an example of this class. The terms anode and anticathode are not always kept separate, and the term anticathode is often used when speaking of the anode.

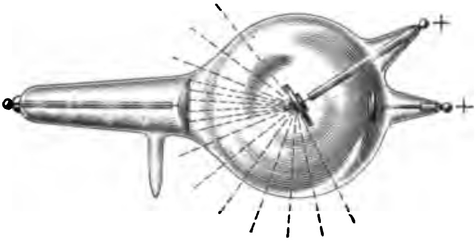

FIG. 27.

81. Modern Forms of Roentgen Ray Tubes.—The more modern form of the Roentgen ray tube is made in the shape of a large globe with tubular extensions projecting in diametrically opposite directions. The globular form serves two purposes. A vacuum tube must be able to withstand a large external pressure, about 700 pounds, and it is found that a globe is able to do so with the least amount of material in its walls. It is important that these are as thin as possible, less than $\frac{1}{64}$ inch, in order not to have too much of the Roentgen light absorbed by the glass. Another reason for choosing the globular form is the greater distance that it allows between its walls and the anode, therefore not exposing the former so much to the heat of the latter.

On the other hand, the Roentgen rays enable the surgeon to correct the position of one or another fragment, and by frequent changes of the immobilizing dressing, repeated corrections can be made. The skiagraph invariably shows the relations of the fragments, even through a plaster-of-Paris dressing. Thus the surgeon always knows if his attempted reposition is correct.

96. The *median* as well as the *radial* nerve may become lacerated by the splintering of the bones. This requires immediate neurorhaphy. Of course, the nerve fragments cannot be represented by the rays, but the location and the character of the fracture, in conjunction with the symptoms in the sphere of these nerves, make the diagnosis positive and dictate the operative steps.

97. In children the skiagraphic anatomy of the elbow-joint may be falsely interpreted. It should be remembered that the osseous nucleus of the interior of the capitulum humeri appears between the second and third years. Another nucleus shows in the internal epicondyle at the fifth year, a third in the trochlea between the eleventh and twelfth years, and soon afterwards a fourth in the internal epicondyle. The nucleus of the internal epicondyle unites with the diaphysis between the sixteenth and the twentieth year; but the other three nuclei form a synosteosis among themselves at the seventeenth year, then constructing the uniform osseous epiphysis which completes its synosteosis with the diaphysis at about the twentieth year.

In very young children the eminentia capitata appears as if entirely severed from the humerus, although the relations are normal. The explanation of this important phenomenon is that the epiphysial tissues are not sufficiently ossified to produce a shadow on the plate. If these points are not thoroughly considered a displaced fracture fragment might be erroneously diagnosticated. The lower epiphysis of the humerus consists of four nuclei, which do not ossify until from the eighth to the seventeenth year. The epiphysis of the *trochlea* as well as of the *olecranon* do not ossify until between the seventh and the twelfth year, which explains why an osseous nucleus is still connected with its neighboring epiphysial nuclei and the diaphysis, connected by cartilaginous tissue, appears as an isolated piece of bone which might erroneously be taken for a fragment.

It must also be borne in mind that in fractures in childhood the process of ossification is influenced by various affections of the bone, like rachitis, for instance.

98. As stated before, inflammatory processes in the elbow-joint are to be viewed from the same points as those of the knee-joint. (See Plate XXXIX and Arts. **76** and **77.**)

99. Fractures of the Olecranon.—Fractures of the olecranon are found more frequently now than before the discovery of the rays. Experience furthermore contradicts the wide-spread opinion that the fracture of the olecranon does not happen before the fifteenth year. It is observed from the tenth year, when the nucleus for ossification appears. In a case of wide diastasis of the fragments, wiring is necessary. While union is taking place frequent fluoroscopic examinations should be made.

100. Fractures of the Coronoid Process of the Ulna.—It was thought that fractures of the coronoid process of the ulna were of rare occurrence. But, as in many other instances, experience with the Roentgen rays has taught that this type of fracture is much more frequent than was formerly believed. The fact that only recently we observed this type in three of our patients during the short space of 4 weeks seems to strongly support this assumption. By realizing that the normal coronoid process cannot be palpated through the thick muscular strata that protect it, the difficulty of making out the broken fragments becomes apparent. The strong lateral ligaments, as well as the annular ligament, which is strengthened by the brachialis muscle, form so strong a protection to the process that a displacement of its fractured fragment seldom takes place. This usual absence of displacement also explains why crepitus is ordinarily not produced. The presence of ecchymosis, as well as of an intense circumscribed pain in the cubital fold produced by strong flexion, are suspicious signs.

The latter would indicate that the process is pushed into the fossa anterior. It should not, however, be forgotten that this valuable symptom is entirely of a subjective nature.

Thus, a positive diagnosis can but seldom be made without using the Roentgen rays. The diagnosis will also determine the prognosis. If there is but little tendency to displacement the prognosis is favorable even when the diagnosis has not been made. But if there is any marked displacement the function of the elbow is greatly disturbed. In such an event, of course, the diagnosis is so much easier the greater that the displacement is. Nowadays this much dreaded condition need not be feared, since reposition of the fragments has become greatly simplified under the guidance of the rays.

The after-treatment is best conducted in a rectangular dressing of plaster-of-Paris. In the cases referred to the fragments were invariably found in a displaced position so that they projected into the joint, interfering with free motion. The projecting bone mass therefore had to be chiseled off.

In the case of a girl of 14 years, fracture of the lower end of the humerus and of the coronoid process of the ulna had occurred. Radial paralysis and acute muscular contraction followed to such an extent that the arm became perfectly useless. Under the guidance of the rays the protruding coronoid fragment was removed and the compressed nerve relieved. Whether after an elapse of 6 years since the injury this deplorable condition will still be remedied, has not been ascertained, the patient still being under treatment.

101. Fracture of the Diaphysis of the Ulna.—Fracture of the diaphysis of the ulna is known to have a great tendency to displacement. If pressed against the radius, synosteosis may take place, thus rendering pronation and supination impossible. For correction, compare the principles emphasized in Art. **106** on the fracture of the shaft of the radius.

102. Fissure of the capitulum ulnæ is found in connection with the fracture of the carpal epiphysis of the radius. (See Art. **109.**)

In *simultaneous fracture of the ulna and radius*, malunion is

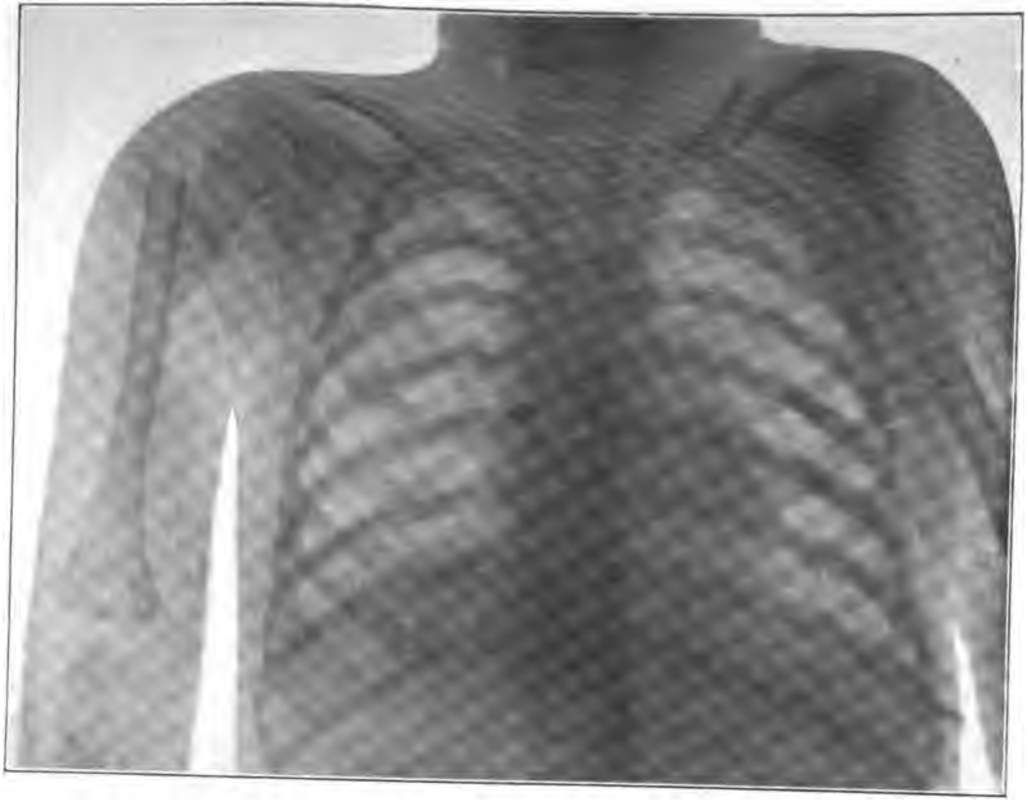

PLATE XXVI.

Deformed Union After Fracture of the Surgical Neck of the Humerus. (Note the Normal Relations of the Normal Shoulder and of the Thorax).

often observed. Plate XXXII shows deformed of radius and ulna in a laborer of 35 years. The fragments overlapped and became adherent by fibrous tissue in juxtaposition. Osteoclasis being impossible, severing of the fragments had to be accomplished by the chisel. In the case of a man of 39 years, who suffered fracture of both forearms by extreme violence, union failed to take place after 5 months. Skiagraphy revealed overlapping of the four bones. Both forearms showed false motion and their function was destroyed. Osteoplasty was performed under the guidance of the skiagraph.

The right forearm permitted of perfect reduction so that the fragments, after being refreshed, could be united by silver-wire. The bones of the left arm could not be pulled into proper position, wherefore they had to be shortened. A segment was cut out from one end and an acute triangle from the other in each bone, so that they could be rejoined without the use of silver-wire. A plaster-of-Paris dressing was then applied, through which skiagraphic examination showed the fragments in good apposition. The result was a perfect cure.

THE RADIUS.

103. The radius gives the surgeon more trouble than any other bone of the human skeleton. If it is only realized that fracture of its lower epiphysis is the most frequent fracture type —at least 18 per cent. of all fractures—its importance becomes evident at once.

104. Fractures of the Radial Head.—Isolated fracture of the head of the radius was regarded as being very rare. If the fragment is entirely severed, it will be recognized by palpation as a separate piece of bone. In addition it will not share the motions of the arm while alternately turned in pronation and supination, and in that case crepitus is seldom absent. Intense pain may point to the seat of the fracture, and sometimes it may be guessed by simple inspection, the biceps drawing the shaft forwards and causing a slight projection. But whenever there is an entire absence of displacement, contusion, or distortion, this error is apt to be made, particularly so when the swelling following the injury veils the symptoms, abnormal mobility especially not being noticeable. In former years it was only under anesthesia that such cases were once in a while diagnosed.

105. Fissures of the Radial Head.—It is evident that the diagnosis of the fissure of the radial head is still more difficult. It would seem that until the discovery of the rays its presence could never be clearly ascertained, and there can be no doubt that with our increasing knowledge and experience this fissure, also, will be recognized more frequently.

The following case will serve as an illustration. A woman, aged 24 years, in falling down stairs struck her right elbow against a piece of iron projecting from the stairway. She consulted a physician at once, who found the elbow much swollen and painful. No signs of a fracture were then detected.

Two days later the arm was in a right-angled flection and the region of the elbow-joint showed considerable swelling and tenderness equally distributed. The area above the radial head showed the presence of ecchymosis.

A skiagraph was taken at once in supination, the patient lying on her back. It revealed the presence of a fissure of the radial head beyond any doubt. There were, in fact, two distinct fissure lines, one running through the circumferentia articularis along its margin, and the other creating a trigonal segment, the base of which was formed by the internal margin of the circumferentia articularis and the tip by a splinter detached from the radial neck.

The treatment consisted in the application of a plaster-of-Paris dressing in rectangular flection, the forearm being kept in semipronation. A second skiagraph, taken 4 weeks later, showed ideal union, the external portion of the circumferentia articularis only protruding farther than it should normally. It also proved how quickly the evidence of the presence of a fissure becomes lost if there be perfect approximation, a circumstance to be borne well in mind from a medicolegal standpoint.

The function of the forearm did not become perfect until 3 months after the injury, the joint showing considerable stiffness at first, which yielded gradually to massage treatment. (See Annals of Surgery, March, 1901.)

Fissure of the radial head being of a decidedly intra-articular character, an effusion in the joint is a natural sequence, which explains the uniform swelling at the beginning as well as the stiffness at a later period. From the observation of this skiagraphic case we may learn that wherever observation shows no tendency to displacement it will be advisable to begin motion at an early stage, say after 10 days, in fissure as well as in fracture of the radial head. In relying on the skiagraphic mentor, our results will be far superior to those of the past. Even in the much-feared cases of fracture of the radial head, where the fragment is considerably displaced, a great deal can be done, or rather prevented, under the guidance of the rays.

The case of a man, age 32 years, gave an opportunity to diagnosticate a fracture of the radial head before the use of the Roentgen rays. This was easy because the much displaced fragment was freely movable. It had seemed that the fragments had been successfully reduced, but a skiagraph taken 12 hours after the injury, through a plaster-of-Paris wire splint, showed that the reposition was not perfect. Anesthesia enabled the displacement to be corrected perfectly in the half-extended position with satisfactory results.

Immobilization should be kept up for weeks in such cases, for premature contraction of the biceps muscle might separate the replaced fragment. If the fragments are not properly retained in place, the production of extensive adhesions might demand resection of the radial head. The same operation might be indicated if small fragments separated from the cartilage remained detached and act like foreign bodies so as to disturb the function of the elbow. The Roentgen rays enable us, in the event of this rare necessity, to trace out definitely the mode of such operations beforehand.

106. Fractures of the Shaft of the Radius.—Fracture of the shaft of the radius has a well-known tendency to displacement. Plate XXXIII illustrates a case in which the upper radial fragment was pressed against the ulna. Reposition was made by bending the forearm in the same manner as a green stick is crossed over the knee, the ulna resting on the edge of a table.

When it was thought that reposition was perfect a plaster-of-Paris dressing was applied. But the skiagraph, taken at once, showed that reposition was imperfect, wherefore a second effort was made, which proved to be successful. In such cases it is advisable to flex the opposite bone as much as possible, that is, in isolated radial fracture bend the ulna and in isolated ulnar fracture bend the radius.

107. Fracture of the Carpal End of the Radius. Fracture of the carpal end of the radius (erroneously called Colles' fracture) is the most frequent fracture type, and is supposed to form at least 18 per cent. of all fractures. We think that it forms 22 per cent.

In no type of fracture have the Roentgen rays disclosed so many errors as in this much-disputed one. In most cases skiagraphy has revealed conditions that were not expected and that have required the original diagnosis to be more or less modified.

It has been found that the anatomic aspects of the various forms of fracture of the lower end of the radius differ more than those of any other fracture, and it is self-evident that such variants are by no means of indifferent importance in respect to treatment.

108. Since March, 1896, when we first began to skiagraph all cases of fracture and suspected fracture that came under our care, we have observed fracture of the lower end of the radius 123 times. In a number of cases fissure of the ulna coexists. Other surprising features are that simultaneous fracture of the styloid process of the ulna and of the scaphoid bone have been found in a great number of cases, complications that were formerly supposed to be of extremely rare occurrence.

Having regard to experience as well as to the information gained by the Roentgen rays, we have tried to classify those

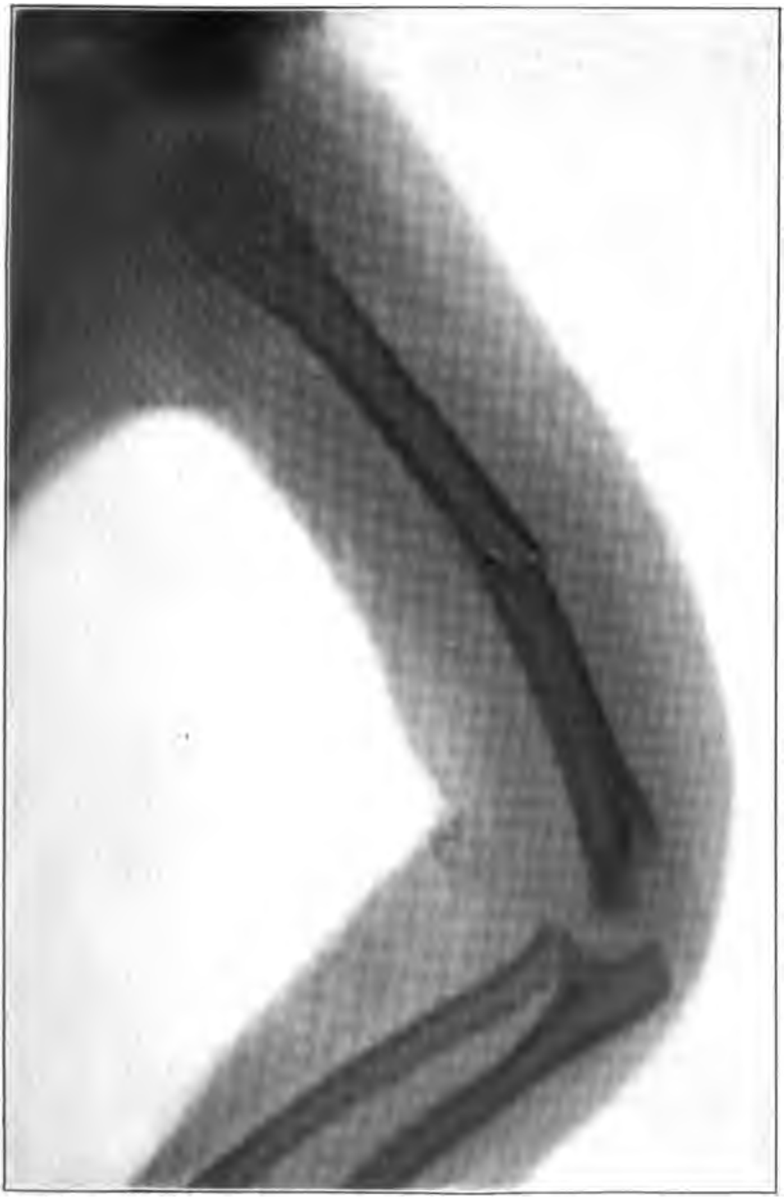

PLATE XXVII.

Green-Stick Fracture in the Middle of the Humerus.

3903

forms of this much-disputed fracture that appear to be most characteristic, and must, accordingly, demand different therapeutic measures, viz.:

1. Epiphysial (chondro-epiphysial and osteoepiphysial) separation.
2. Fissure (fracture without displacement).
3. Complete fracture (simple and more or less displaced and multiple **T**- and **Y**-shaped).
4. Incomplete fracture—infraction (very rare).
5. Fracture of the carpal end of the radius combined with fracture of the styloid process of the ulna.
6. Fracture of the carpal end of the radius combined with fissure or fracture of the lower end of the ulna.
7. Fracture of the carpal end of the radius combined with fissure or fracture of the scaphoid bone (also with the ulnar end, sometimes).

All these different varieties may be intra- as well as extra-articular.

8. Fracture of little bone portions (chips), usually extra-articular.

109. The first modification that the Roentgen rays imposed upon the anatomy of this fracture was our own discovery of the simultaneous injury of the lower end of the ulna. (See International Medical Magazine, May, 1897.) In a study of 123 cases of fracture of the carpal end of the radius, fissure of the ulna was found 26 times (nearly always in adults) while the complete fracture was observed 9 times (during the age from 10 to 18 years). Displacement of the ulnar fragment was rarely present. In 4 cases it was, in fact, insignificant. The direction of the line of fissure and fracture was always transverse. The injury had invariably been caused by a fall upon the hand when in dorsal flection, the history of the case invariably pointing to a high degree of external violence.

110. Considering that in a case of simple fissure of the ulna the position of the fragments remains normal, as there is no diastasis, it is easily understood why a correct diagnosis was hardly possible before the discovery of the Roentgen rays. The tear may, in fact, be so insignificant that only a very distinct skiagraph will show it.

Plate XXXIV illustrates a case of osteoepiphysial separation of the radius combined with fissure of the inner surface of the epiphysial end of the ulna in a lad of 16 years who had fallen down a stone stairway.

Plate XXXIV was taken while the ulnar margin of the hand was slightly lifted, while a former palmar skiagraph created the impression of a normal, non-ossified epiphysis. Another exposure, taken in the lateral position, illustrated the displacement of the fragment markedly. This is another proof of the absolute need, as stated, of taking at least two exposures in different positions in fracture cases.

111. Another technical point deserving attention is that if the exposure is made immediately after a fracture is sustained the fracture line is often not well marked, especially so if there is no displacement of the fragment. After a few days, when the callus formation begins, the line is more marked. The first skiagraph of the case described, for instance, which showed hardly any evidence of the presence of a fracture, was taken 1 hour after the injury. The diagnosis of fracture could be made without the aid of the Roentgen rays in this case, but the simultaneous injury of the ulna would certainly not have been recognized by the old method.

Plate XXXV illustrates the case of a lad of 18 years who fell from the roof of a small house. When the patient first came under observation, 24 hours after the injury, there was considerable swelling of the wrist and marked deformity, which was especially marked at the outer (radial) aspect of the wrist. At the ulnar surface a slight irregularity was noticeable. The skiagraph showed a considerable displacement of both bones, which were in a state of splintering, and a transverse fracture of the scaphoid bone. Naturally, the displacement yielded to forcible bending under anesthesia. A second skiagraph, taken 3 weeks after refracture, showed ideal apposition of the ulnar fragments and fair restitution of the radial.

It was only in five of the cases of simultaneous ulnar fissure or fracture that there were any indications of mobility, and even in these cases the indications were so slight that no diagnosis could have been made without the aid of the skiagraph. Of course, as soon as the skiagraph has given a clear anatomic representation of the condition the palpatory impressions become more certain.

112. In view of the anatomic relations, it is natural that ulnar crepitus was never observed in these cases. Sometimes a slight ulnar deformity was noticeable, which was undoubtedly due to the presence of the bloody effusion within the fissure line. The tenderness localized in this sphere harmonized with this assumption.

From the study of these cases the conclusion may be drawn that, in many cases of fracture of the carpal end of the radius producing the so-called sideward pushing of the ulna, there is in fact a fissure or fracture of the ulna which, on account of its insignificant clinical signs, was not recognized in former years. We have no doubt that with the greater popularity of the Roentgen rays the comparative frequency of the injury will be confirmed by many physicians.

113. It should be borne in mind that only a very good tube clearly reproduces the presence of a fissure. A soft tube should be chosen and the exposure should be long enough to show the structure of the bones distinctly and the soft tissues hardly at all, as, for instance, in Plates III, IV, IX, and XII.

It has repeatedly occurred that on account of a mediocre skiagraph a fissure line was not detected which appeared well pronounced in a blameless one. Such facts explain very well why some surgeons disputed the reliability of other fellow observers. Dr. A, for instance, insisting upon his diagnosis, and properly so, while Dr. B, with his poor skiagraph of the same case, asserts that he did not find the fissure line. Of course, Dr. B's opinion is thoroughly honest, but absolutely erroneous, nevertheless.

Especially during the first few days after the injury the presence of a fissure is more easily overlooked than later, when callus formation begins. Only the most thorough observation brings out the necessary points with clearness, and it may be repeated that two synchronous exposures must be taken—one in the dorso-palmar and one in the lateral radio-ulnar position. It is also advisable to make several exposures during different stages of after-treatment. Now we hear a number of confrères say: "This is all very nice and interesting, but wherein does the practical benefit of this detailed anatomic knowledge consist?" To this we must reply that the practical benefit is enormous, since we now understand why simple fissure heals under or in spite of any treatment. Wherever no tendency to displacement exists, no replacement or, to use an ordinary term, no reposition is required.

If the surgeon, led by anatomic knowledge, does the same that the quack does on account of his ignorance, namely, leave the healing process to nature, the same good result may finally be obtained. The scientific treatment of fissure will not alter any of its mechanism, but it will, at least, have the value of giving greater comfort to the patient. Such comfort is obtained by encircling the wrist by a bracelet of moss-board. This appliance immobilizes the wrist sufficiently, and at the same time it permits enough motion to counteract the formation of adhesions in the sheaths of the tendons. The patient carries his hand in a sling in such a manner that the ulnar margin rests on it. Thus, free motion of the hand is permitted. The patient is told to move his fingers as in playing the piano, and we found it very useful to advise him to grasp marbles of moderate size and to roll them around in the palm of the hand. Patients are generally willing to keep these marbles in their pockets, and play with them while reading, conversing, or walking around. If motion is thus kept up constantly the massage treatment, as well as forcible motion, can be dispensed with, and recovery is perfect in 4 weeks or even before.

In complete fracture without tendency to displacement, a plaster-of-Paris dressing may be applied immediately after the injury is sustained. But whenever displacement of the

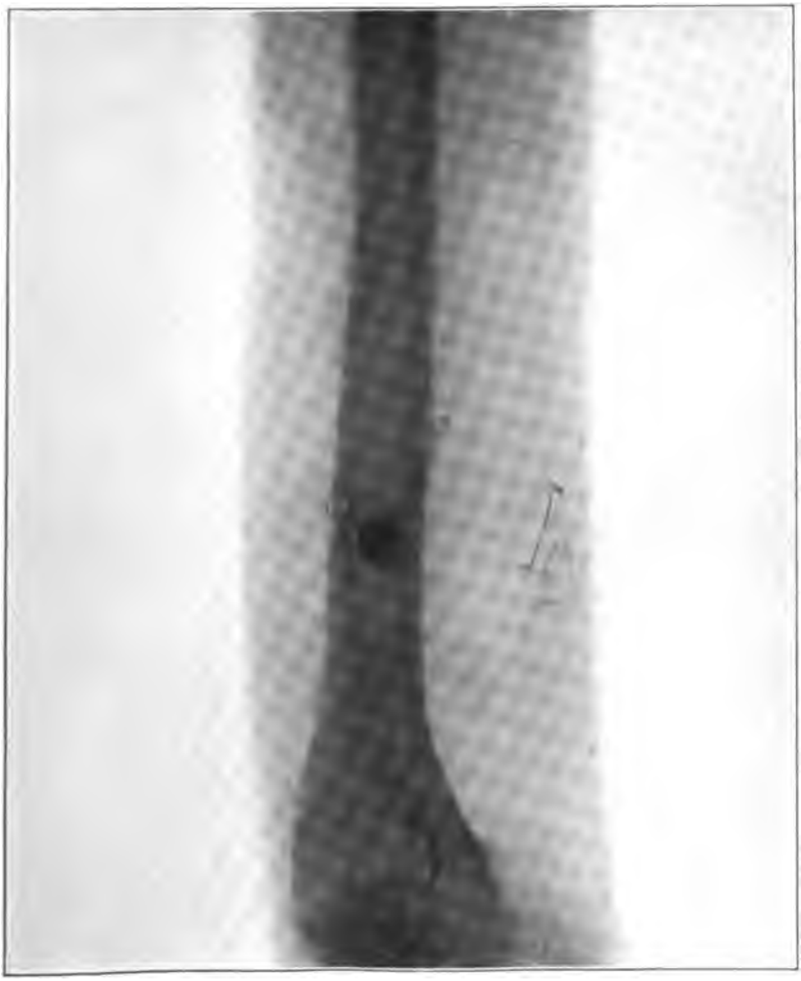

PLATE XXVIII.

Localization of Bullet in Upper Arm by Wire Letters.

5906

fragments takes place, accurate reposition is the condition sine qua non. This is done best by forced extension, the hand being grasped as in a firm hand-shake, with a downward pressure by the surgeon's thumb, while counter-extension is used on the forearm, which is flexed rectangularly. If an assistant is at hand, the surgeon grasps the four fingers with his left and the thumb with his right hand, while the assistant uses counterpressure at the elbow. If this procedure should fail, anesthesia must be employed. If there is simultaneous injury of the lower end of the ulna showing displacement, like in Plate III, for instance, great care must be taken to press the fragment into its normal place.

114. Even in multiple fractures, especially in the much dreaded T-shaped variety, the articular arch of the radius may be restored by repeated efforts of reposition controlled and corrected by the Roentgen rays. Even the routine surgeon is often astonished to find, after he thought he had accomplished a perfect reduction, how badly he has succeeded in his alleged reposition, one small item generally having been overlooked by him. Fortunately malposition can often still be corrected after 2 or 3 weeks.

Keeping the fragments well adjusted in a proper position is quite difficult sometimes. We have, however, always been able to secure this by very simple methods. A long adaptable wire splint is applied while forced traction is made; the splint reaches at the flexor side of the arm from the tip of the fingers to the elbow. If the direction of the displacement is *upwards* (silver-fork shape), a pad of adhesive plaster is attached to the dorsal integument above the fragment. Then a short, narrow splint of wood is applied on the dorsal aspect of the arm, reaching from the metacarpophalangeal joint to 4 inches above the wrist, and is kept pressing downwards by the application of a gauze bandage.

If the tendency to displacement is *downwards*, the same procedure is carried out in the opposite manner, the wire splint being applied on the dorsal, and the wooden splint on the palmar side of the arm.

If the displacement be *sidewise*, which is most marked when there is a simultaneous injury of the ulna, immobilization must be carried out on entirely different lines. The adhesive plaster pad must then be applied laterally to the fragment, two long, narrow, wooden splints being used at the same time. One of these splints, being a little broader than the diameter of the bone, begins at the metacarpophalangeal joint of the thumb, and the other at the same point of the little finger. Both extend up to the elbow, the same as the long wire splint. If there should be any displacement in the opposite direction, the pad must be applied on the ulnar side. No dorsal splint is used in this variety. After the dressing is finished, the skiagraph verifies the proper position of the fragments. In case the tendency to displacement cannot be overcome, a plaster-of-Paris dressing is applied, while forcible extension and counter-extension are used. Whether the position of the fragments is correct should be ascertained by the rays after the plaster-of-Paris dressing is applied.

If, after the lapse of a week, agglutination of the fragments is obtained and no deformity is evident, then the soft tissues must receive consideration. It is only then that short splints are in order. They consist of well-padded pieces of wood extending from the metacarpophalangeal joint up to the middle of the forearm. After another week a bracelet, such as is recommended for the treatment of simple fissure, is so applied as to permit of the free motion of the fingers (see Art. **113**). The patient is told to move his fingers as in playing the piano; also to use the marbles as described in the treatment of the fissure.

After the third week massage treatment is indicated, active as well as passive motion of the joint being employed at the same time. The results of these simple methods are just as good if not better than those obtained by any of the numerous much complicated apparatus often advised for the same purpose. If all the points of these manipulations dictated by simple common sense are observed, and if their proper execution is certified by the skiagraph, surgical clinics will no longer furnish so much testimony of deformities and functional impairment following fracture of the carpal end of the radius.

Of course, for the rich man who does no work and for the laborer who does only rude work, the faulty position may be of little importance. But whoever must do delicate work will be greatly damaged by even a small degree of functional disturbance. In fact, it is the displacement of the fragment, be it even very small, which causes the chain of later disturbances.

115. These doctrines are so simple that it seems almost unnecessary to repeat them. And yet they are frequently violated. The functional impairment following some fractures, especially the formation of adhesions in the vicinity of the joints, has led a number of surgeons to enunciate this dogma: "The most important part in the treatment of fracture is the treatment of the soft tissues." They claim, in other words, that because the function of the soft tissues—for instance, of the tendons—is impaired after a non-reduced fracture, the soft tissues should have received more attention instead of the displaced fragment having been simply reduced to where it belongs. Nothing, in fact, is more contrary to common sense than this dangerous maxim, which is based on correct observation, but incorrect interpretation. It should always be considered that the relations of the soft tissues to the bones are like that of the clinging vine to the sturdy oak.

Galen says that the bones give the human body form, erectness, and firmness. It is evident that an injury of the bones impairs these three fundamental factors. The most important step toward repair must thus be taken in the foundations rather than in the superimposed structure.

If there is displacement of the bone fragments, undue pressure is necessarily made upon the soft tissues; *non-reduction means persistence of pressure*, the unfortunate consequences of which are well known. *Reduction means the relief of pressure.* Of course, the act of injury cannot be undone by the mere cessation of pressure; but the influence of the injury on the soft tissues—the influence of the pressure, in fact—lasts only a short time, and is insignificant after early reduction; there is then but little inflammation, and consequently little exudation, and therefore repair is easy. This means that the premises of adhesion formation are wanting, and clinical observation shows that if there was perfect reposition, the joint as well as the sheaths of the tendons are found free, provided the immobilization has not lasted for an extraordinary length of time. In such cases of severe functional disturbance of the joint produced by the agglutination of the fragments in a displaced position we have repeatedly succeeded in reducing the deformity by osteotomy performed under the guidance of the Roentgen rays. In every instance the functional result has been very satisfactory.

116. In addition, it may be urged that there is another and frequent simultaneous injury, namely, the fracture of the styloid process of the ulna, which was discovered long before Roentgen by Nèlaton and Velpeau, but has often again been disputed.

The Roentgen rays bring the great old French surgeons to honor again. Our statistics show a participation of the styloid process in 31 per cent. of the cases. Kahleyss, in his monograph, finds a frequency of 78 per cent., which seems to us to be rather high.

In this country, especially Pilcher, Freeman, Corson, Thomas, Don, Haughton, and Colton have contributed their share to the better understanding of this condition. How important early recognition of the displacement of the broken styloid process is may be evident from the case of a woman of 30 years who had sustained a fracture of the carpal end of the radius, but which was not skiagraphed until 8 weeks after the injury, when she still suffered from a stiff, swollen wrist. The skiagraph revealed inversion of the styloid process of the ulna, which explained the intense pain caused by any effort of bending the wrist-joint. Had this condition been recognized at an early stage, a small amount of pressure would have sufficed to push the fragment into its proper position, while after the elapse of 8 weeks perfect restitution could be expected only by removing the little obstacle with the chisel.

117. Another interesting injury is the fracture of some of the carpal bones, at first discovered by Destoit and Gallois. In realizing that the fracture of the carpal end of the radius is not only expressed by a tear, but also that it is produced by a

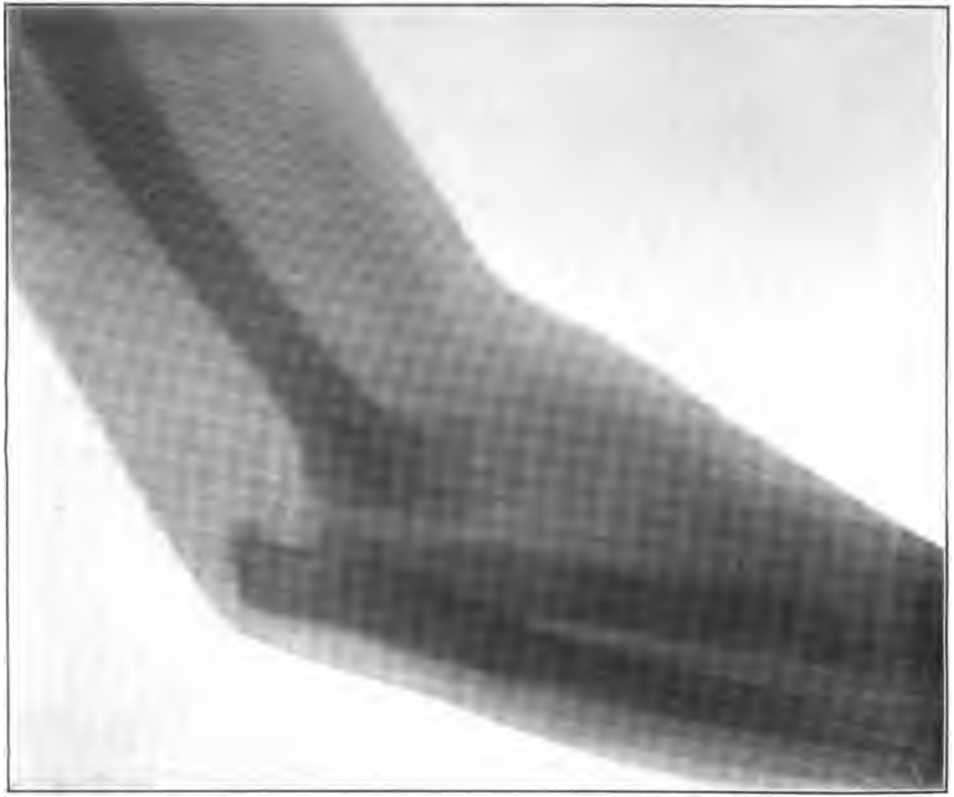

PLATE XXIX.

Backward Dislocation of Elbow.

combination of tearing, pushing, and counter-pushing, it is easily comprehended why the effect of the violence is not confined to the radial epiphysis but also either extends to the ulna (ulnar inversion of the radial fragment described above) or is transferred to the carpus. It has been maintained that the preference is for the semilunar bone (Gocht, Kahleyss). Destoit and Gallois, also, found fracture of the unciform bone. Most of these reports, however, refer to the isolated fracture of these bones. It seemed repeatedly that we had detected these injuries so long as we had a palmar exposure only, but lateral projection showed that the shadow of the adjoining carpal end had deceived us. ("Errors Caused by the False Interpretation of the Roentgen Rays," New York Medical Record, August 25, 1900.)

118. But another injury, namely, *transverse fracture of the scaphoid bone*, was observed in 9 per cent. of our cases. In realizing that the scaphoid is the most important of the carpal bones articulating with the radius, it can easily be understood that the same mechanical combination following external violence, as alluded to in connection with ulnar coinjury, holds good in regard to the scaphoid bone, viz., that the pressure is continued to its arch, which must then yield. The direction of the force is straight, in this instance, instead of being sidewise, as in ulnar coinjury, the hand being held in pronation and radial inflection. This also explains the enormous intra-articular effusion sometimes present, which is responsible for the great tendency to the formation of adhesions in these cases. In all the cases observed by us an extreme degree of violence was the etiological factor.

Based on this experience, we may venture to call this injury a typical one, found as a consequence of an extreme degree of violence. Previously, the extensive swelling caused by the abundant effusion was attributed to the radial injury only. It is this injury that is especially prone to cause bony ankylosis of the wrist. Now, in diagnosticating this injury at an early stage, we possess the power to counteract this occurrence by early motion.

119. The more we learned to modify our diagnosis by the Roentgen rays, the oftener have we found that the most convenient diagnosis of contusion or distortion in many instances is, in fact, nothing else but a makeshift for a fissure or fracture. Aside from the fracture of the whole styloid process of the radius itself, the stripping off of small bone portions is of frequent occurrence. In such cases massage treatment is manifestly inappropriate; the treatment to be carried on is the same as for the treatment of fracture, viz., immobilization. This should be kept up at least for the first week after the injury and after the little fragments were redressed.

Such chips are sometimes not larger than the head of a pin, and if they are separated from the dorsal or palmar surface of the radius they may not be at all conspicuous on the skiagraphic plate when it is taken from the palm or the dorsum, the thick shadows of the radius veiling them. A lateral exposure will, of course, show them distinctly. A small bone-chip may be seen associated with non-displaced fracture. If the massage treatment, so commendable in contusions, is used in these cases, it is not surprising that the patient becomes rebellious. The Roentgen rays explain this phenomenon well. It is, in fact, not at all indifferent whether a simple bloody effusion or keen edged bone fragments are kneaded.

120. The study of the various diseases and injuries of the hand was greatly benefited by the discovery of the rays. A large number of alleged dislocations and contusions are, in fact, either complete fractures in adults or separation of the epiphysis in children. Especially fractures of the metacarpus proved to be by no means as rare as was thought formerly. In most cases displacement of the fragments being absent and the other metacarpal bones serving to a certain extent as splints, it is natural that the results in these cases were nearly always good no matter what treatment was employed; the *post hoc, ergo propter hoc* being enough for the superficial observer. If, however, he had used the Roentgen rays he would have been not a little surprised to find in such a case the evidence of a fracture; while at the same time he could congratulate himself that in spite of his treatment for simple contusion the result was so perfect.

In the event of displacement the result would be somewhat different. If the displacement is in the dorsal direction, it is not only easily recognized, but also reduced and kept in place without difficulty by the coaptation splints. But if the displacement, as it often occurs, is sidewise, the result may be very unsatisfactory, the remaining deformity and disturbance of function being considerable. If a common laborer is concerned but little inconvenience may be caused by it; but if a person whose hands must do delicate work, like a musician, watchmaker, cabinetmaker, or last, but not least, a physician, for instance, is the victim, badly united metacarpal fragments of the right hand may seriously interfere with his professional work.

Reduction of the displaced fragments never offers any insurmountable obstacles; but to hold them in place is a far more complicated task, and the recurrence of the displacement under the usual immobilizing methods shows their insufficiency in the end.

121. The question now is: what is to be our guide in estimating the value of a given immobilizing method before consolidation can have taken place? In former years we used to judge the value of one or the other method by the final result. But, now, just as we estimate the value of a germ-destroying method first of all by bacteriological experiment, so we are able to judge by irradiation from the very beginning. If the immobilizing dressing is perfect, the formerly displaced fragments must be found in exact apposition when skiagraphed through the dressing. Various experiments have shown that the metacarpal fragments are invariably held in place by elastic pressure. For this purpose two rubber drainage tubes of moderate size are chosen, which are lightly pressed into the adjoining interosseous spaces so that they fill them up to a certain extent. They are kept in place by strips of adhesive plaster. Thus the recurrence of the displacement is prohibited. The whole is surrounded then by a moss-splint, a material that after being dipped in cold water adapts itself to the contours of the hand like a plaster-of-Paris splint, over which it possesses the great advantages of being absorbent and much lighter.

In the case of a young Italian who sustained a fracture of the fourth metacarpal bone in its middle as a result of direct violence (he struck his brother in the face with his fist), considerable lateral displacement was produced. Reposition was easily accomplished and the fracture area was carefully surrounded by narrow pads that were supported by adhesive plaster. A long palmar extension splint was then applied. There was no swelling of the fingers nor any sign of discomfort. But when examining the metacarpus 2 weeks later with a view to leaving off the splints, it was found that the fragments had slipped by each other again. Other means of immobilization were seriously considered. After filling up the interosseous grooves between the fourth metacarpal bone and the little finger on one side and the third one on the other with two rubber drainage tubes, a skiagraph was taken, which showed the fragments in ideal apposition. Shortly afterwards the rubber tubes were removed and the displacement recurred at once. From this we learn that it is unwise to rely upon the old dictum that metacarpal fractures show perfect consolidation after 3 weeks. We should consult the Roentgen rays before satisfying ourselves as to the question of impeccable union.

122. Recognition of the various types of *dislocation of the thumb* has also become easy. In former years old non-reduced dislocations of the thumb were a frequent occurrence at surgical clinics.

Plate XXXVI shows dorsal dislocation of the second phalanx of the thumb in a woman of 26 years. Reduction could still, after 3 weeks, be accomplished by the use of a strong blunt traction-forceps. *Fractures of the phalanges* were also often overlooked. While a thorough examination should always reveal the presence of a transverse fracture of the phalanges, the longitudinal type could not be suspected under ordinary circumstances. Plate XXXVII shows the third phalanx of the ring

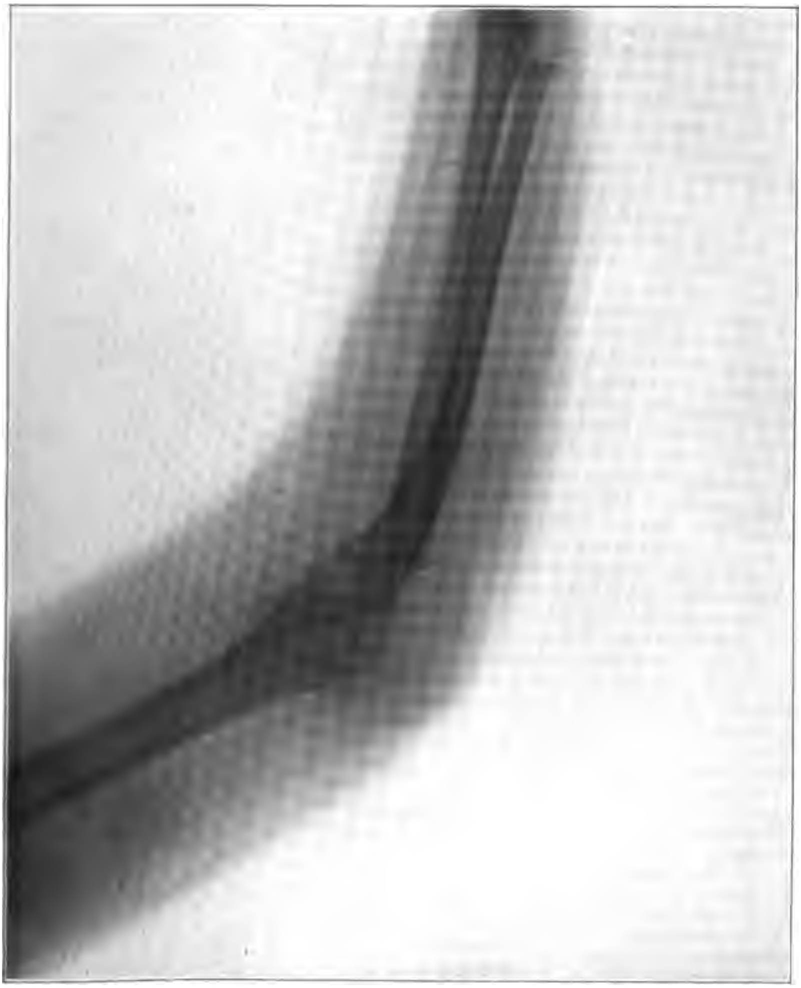

PLATE XXX.

Osteoepiphysial Separation of the Lower End of the Humerus.

3905

finger of a lad of 15 years split nearly in halves. The skiagraph suggested pressing the two fragments together and keeping them in apposition by a strip of adhesive plaster. We confess that we never knew of the existence of this fracture-type before.

123. *Tuberculosis* of the carpus, metacarpus, and phalanges, frequent in children, can be well studied and treated under the guidance of the rays (see Art. **136**).

124. It was our privilege to discover a pathological condition (tenontitis and tenontothecitis prolifera calcarea) which, as far as our knowledge goes, has never before been described. It concerned a Russian tailor, age 42 years, who noticed a small and painless swelling formed in the dorsal surface of his right hand 11 years before. The size of this swelling increased gradually, but sometimes it seemed to be somewhat less. At last it became quite large, but until it grew painful no medical advice was sought.

When first examined a globular tumor was noticed on the dorsum of the right hand, the size of which corresponded to that of a moderately large apple. Its surface was red, its consistence irregular, some parts of it being hard, while others appeared soft to the touch. The center of the tumor was occupied by a large ulceration, which was surrounded by several fistulous tracts from which turbid sero-pus issued.

The first impression was that the tumor represented an osteosarcoma and it was feared that speedy amputation would be indicated. It was decided to consult the Roentgen rays, which proved to be a valuable means of information, since the true condition was at once precisely defined. A skiagraph taken under the influence of intense irradiation showed that the third metacarpophalangeal joint was the seat of a focus of inflammation. The first phalanx was grown together with the metacarpus. The cortex of the condylar side was totally destroyed, appearing as if scooped out with a gouge. By faint irradiation the outlines of the tumor appeared well marked.

A third skiagraph taken under powerful irradiation and a short exposure showed the bones faintly, but permitted distinct recognition of the various shades of the tumorous portions.

The light areas showed the suppurating portions while the dark shades corresponded to the calcareous areas. These, as shown also by the subsequent operation, were the predominating elements of the tumor. It now became evident that there was a chromic inflammatory process probably of a tuberculous nature.

The extirpation showed the defect of the bone filled with yellow cheesy masses, the synovial membrane being partially destroyed at the same time. But the most surprising feature of the condition was that the extensor tendons of the digits, excepting the thumb, appeared as if cemented into one mass of mortar. In dividing this mass the knife caused a loud grating sound.

Of the tendon on the third finger only a few rudimentary fascicles had remained, so that it had to be sacrificed entirely. The fascicles of the second and fourth extensor tendons were kept apart by the concretions. They were, in fact, so much incrusted that only a small portion could be felt. The weight of the whole amount of the calcareous mass removed proved to be 80 grams.

Microscopical examination showed round-cell granulations and the presence of staphylococci, but no evidence of tubercle bacilli. There were also deposits of phosphates and carbonates of calcium. The fragments of the tendons showed granulation of the circumfascicular and the intrafascicular connective tissues.

Hematoxylin colorized the degenerated tissue dark-brown violet, and picrocarmin changed it into red. Recovery was slow and did not become perfect until 6 months after the operation.

Now, what was the integral character of the disease? There was a much degenerated (cheesy) tissue in the state of necrobiosis which seemed to have a sort of magnetic effect, so to speak, on the dissolved calcareous salts, inducing them to amalgamate. Such petrifactions are found in tuberculous (cheesy) foci of the lungs and not infrequently in endocarditis, pericarditis, in old pleuritic bands, uterine myomata, and in renal epithelium. In the walls of blood-vessels as well as in degenerated thyroid glands we have had an opportunity, by means of the Roentgen rays, to define the mode of petrifaction.

The tendons and their sheaths seem to be but seldom the seat of predilection for calcareous deposits. Still, with the increasing popularity of the Roentgen rays, more light may also be thrown upon the pathology and significance of this hitherto unknown disease for which we suggest the name of tenontitis and tenontothecitis prolifera calcarea. (New York Medical Journal, April 27, 1901.)

125. As previously mentioned, the great scientific and practical value of Roentgen rays is also evident in the study of *congenital malformations of the bones.* Skiagraphy of the extremities especially has given more valuable information than dissection. The exact anatomic diagnosis that it enables us to make informs us whether surgical interference in a case of malformation is possible and, if so, outlines clearly our modus operandi beforehand. The ingenious operations of Bardenheuer (division of the ulna for carpal implantation) and von Eiselsberg (transplantation of the toe), and the work of Kirmisson, Vulpius, Middleton, Pagenstecher, von Bardeleben, Joachimsthal, Schede, Lambertz, and Grunmach furnish most brilliant testimony to our progress in this direction.

126. Polydactylism.—Fortunately, the most frequent abnormality is the one that can be most easily remedied, namely, polydactylism. If there is but a rudimentary finger attached loosely by a pedicle and containing no phalanges at all, removal is very simple.

But when, as is the rule, there is a true supernumary digit articulating with another phalanx or the head or side of a metacarpal bone, the site of exarticulation must be well known before the operation. Otherwise, the better developed phalanx may be sacrificed.

127. Syndactylism.—Syndactylism, while not so frequent as polydactylism, also represents a large group of cases of malformation of the upper extremity and is likewise amenable to operative interference.

In a case of syndactylism in a boy of 4 months the second, third, and fourth digits appeared to be fused together, each one of them, however, possessing its own nail. The skiagraph showed fusion of the first and second phalanges of the third and fourth digits, while their third phalanges were free. The little finger was more developed than the slightly deformed thumb. The carpus was not yet ossified, and showed no shade therefore. Under the guidance of the Roentgen rays it was easy to divide the phalanges. The middle finger was protected easily by a large longitudinal flap from the dorsal surface of the hand. The other two fingers were covered with their integument, longitudinal flaps being formed from the palmar surface for the second finger, and another one from the dorsal side of the fourth. The final result was good.

128. Congenital Deficiencies.—Congenital deficiencies are naturally much less amenable to correction. But that surgery is not without resources even in desperate cases of this kind is made evident by the transplantation of a toe to the hand, successfully undertaken by von Eiselsberg.

In *brachydactylism*, combined with ectrodactylism, the Roentgen rays have proved to be of great value. In the case of a boy, age 3 months, there were five rudimentary fingers. The skiagraph showed the presence of one phalanx of the thumb and one of two phalanges of each of the other fingers.

Under the guidance of the Roentgen rays a flap operation was performed, on the principles set forth in the case described in Art. 127, between the first and second finger rudiment. Thus a fairly good thumb was created. The case, however, offered two more points of interest. In the first place there was a congenital fracture of the ulna and radius at their lower third, as was also illustrated skiagraphically. The forearm could be bent easily at the seat of the fracture. After wiring the fragments, union became perfect.

There was, furthermore, congenital constriction at the region of the surgical neck of the humerus, where a deep furrow encircled the whole circumference of the arm. Palpation was unable to detect any soft tissues between the integument and the bone. An exploratory incision revealed the presence of fragments of the biceps, triceps, and deltoid muscles. Their

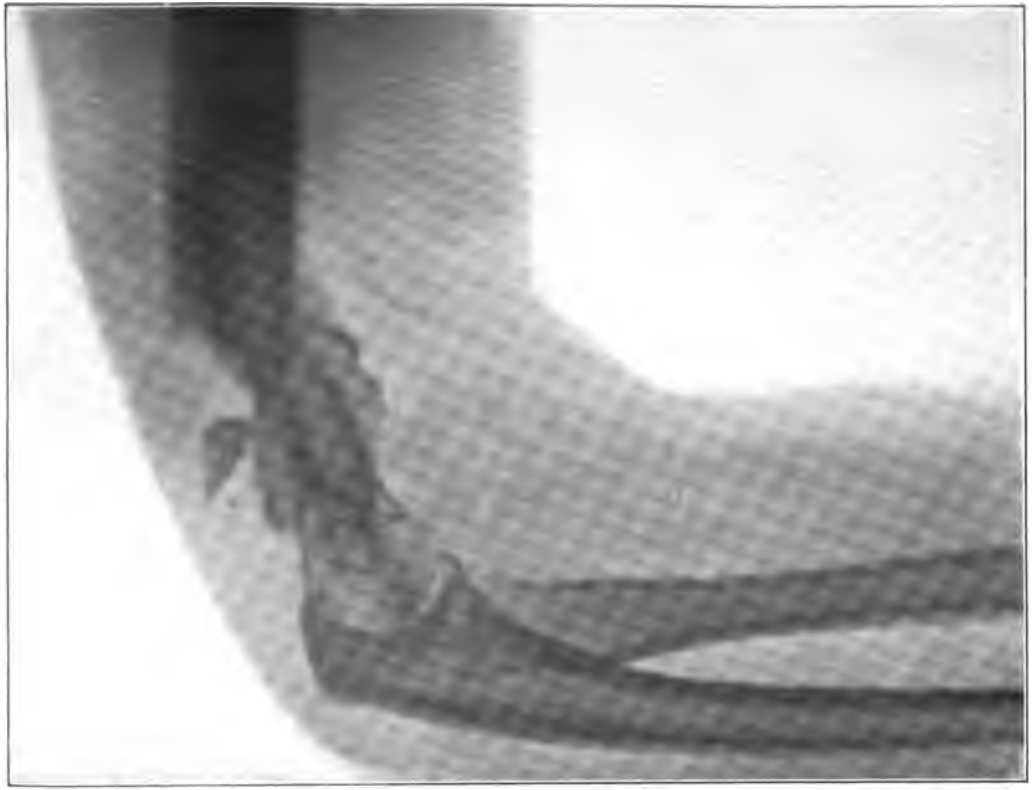

PLATE XXXI.

Multiple Fracture of the Lower Third of the Humerus.

edges were refreshed and united with catgut. For relaxation two deep wire sutures were introduced from without. The result is fair according to the last report, 18 months after the operation.

It may be added that the otherwise well-developed hand showed a moderately deep constricting furrow near the metacarpophalangeal junction of the middle finger, which did not seem to demand surgical interference since the skiagraph showed its integrity otherwise.

It seems to us that this special branch of surgery does not receive the attention it merits. Considering that in the lower animals, as long as in the embryonic stage, regeneration of large portions of the head and trunk are possible, it should be expected that the new-born child—in a smaller proportion of course—also offers more chances for regeneration than the adult. If the germinal layer is only present, further development of the tissues can be looked for. If a part of a phalanx is properly severed, its individualization is a matter of great probability provided the bridge remaining has preserved sufficient vascularity for nutrition, that there is no overextension of the flap, and that the most minute aseptic precautions are taken.

Foreign bodies are easily shown in the hand, especially needles in the palm often coming under the observation of the busy practitioner. Plate XXXVIII is only presented to show that even the eye of a small needle can be well shown.

129. Remedying a Club-Hand.—In a case of congenital club-hand associated with absence of the radius and ulna, only three fingers and three metacarpal bones were present, as became evident by skiagraphic examination.

The left arm of the boy was normal with the exception of the thumb, which was partially ectrodactylic. An attempt was made to improve this deplorable condition by creating a thumb after the principles carried out in the case just described. For this purpose a dorsal incision was made down to the first metacarpal bone, which was divided longitudinally, thus making a kind of bifurcation. The phalangeal end was severed entirely, but the carpal end, after being fractured longitudinally, was left in slight connection with the metacarpal bone. Thus a new bone was obtained that was surrounded by dorsal as well as palmar flaps. There was little trouble during the after-treatment. How far this new fourth finger can be utilized can, of course, not yet be known, the child still being under treatment. (See "Congenital Malformation of the Upper Extremity," New York Medical Journal, June 29, 1901.)

INFLAMMATORY PROCESSES AND NEOPLASMS OF THE BONES AND JOINTS.

130. Many limbs have been sacrificed by unnecessary amputation and many lives have been lost by deferred amputation on account of errors in differentiating the various inflammatory processes from new growths of the bones and joints. The Roentgen rays have opened entirely new fields in this sphere. If they are not always able to give a positive answer, they often by the way of exclusion give a chance to arrive at a correct diagnosis.

If in a case of obscure swelling of the knee-joint, for instance, the Roentgen rays reveal nothing else than the absolute integrity of the joint, osteitis, tuberculosis, syphilis, or a bone-injury can be excluded. It is certain then that only the soft tissues are involved. Thus we may, in conjunction with other clinical symptoms, be satisfied that we have to deal with a rheumatic swelling or a neoplasmoid formation of the soft tissues only. But in many instances the Roentgen rays give positive information.

131. Periostitis.—Again, in periostitis as well as in osteomyelitis the skiagraphic signs are well marked. Abscesses can not only be localized, but their extent is so well outlined that the technical steps of the operation can be definitely traced in advance. The feeling of security the surgeon has while proceeding under the mentorship of the skiagraph gives a satisfaction unknown in former years, when often the whole femur had to be exposed simply in order to ascertain whether all foci were detected. If the Roentgen rays show but one focus, no other regions of the bone need be attacked.

In such cases a preceding trauma often opens the avenue of infection. The pain, the edema, the fever, and general debility may be sometimes so little marked that differentiation becomes difficult. The skiagraph not only clears this difficulty of diagnosing this disease, true etiology of which is still so obscure, but it also furnishes a trustworthy guide for the operative technic at the same time.

132. Osteomyelitis.—Osteomyelitis is of a decidedly infectious character, generally due to the invasion of the staphylococcus, which fortunately has a tendency of forming circumscribed foci in the vascular tissues of the bone, viz., the medulla and sometimes the periosteum. The predilection of osteomyelitis is for the long bones of young individuals. It is self-evident, therefore, that the early recognition of osteomyelitic foci renders the prognosis of their evacuation extremely favorable.

In the case of a woman of 20 years the slow onset of the symptoms did not seem to indicate an acute inflammatory process. Pain being present only temporarily, the fear of a malignant growth was apparently not unjustifiable. The skiagraph at once did away with all anxiety, since it revealed the presence of periostitic proliferations and a circumscribed osteomyelitic focus at the middle of the humerus. The focus was easily exposed by the chisel under the mentorship of the skiagraph. That the skiagraph had also spoken the truth by demonstrating the integrity of the remaining portions of the humerus was shown by the speedy recovery of the patient.

The focus was distinguished by its light shade in the midst of the dark shade of the cortex. The regularity of the cortical line distinguished it from osteosarcoma and the absence of distention from osseous cyst.

133. Necrosis, and other later stages of inflammatory processes can be represented still more distinctly. The size and shape of a sequestra can be easily made out. It can furthermore be ascertained how they are located in their bony coffin, whether they still adhere or are exfoliated. Under the guidance of the Roentgen rays extraction is very easy.

In the case of a man of 23 years who had crushed his little finger, amputation was deferred until septic tenonitis and tenontothecitis had developed. The extensive tissue necrosis in the muscular interstices of the forearm necessitated free and deep incisions, which showed the radius as well as the ulna denuded of its periosteum. Amputation was therefore authoritatively advised, but nevertheless the chances for further conservative treatment were taken. Fortunately the process became confined to the forearm and recovery seemed to make rapid progress. Only a small fistula at the dorsum of the forearm did not close. The repeated introduction of a probe did not reveal the presence of rough bone, and we were inclined to suppress our suspicion of the presence of a sequestrum. Our surprise was great when the Roentgen rays revealed the presence of a large splinter exfoliated from the inner portion of the radius, the surface of which was covered by osteophytes. The direction of the skin incision, slightly oblique, was dictated by the position of the sequestrum as shown by the skiagraph. When the sequestrum was reached it was found to be covered by thick, fibrous tissue at the upper surface, while the inner and lower surfaces were exposed. This explains why the introduction of the probe gave no positive information, since it had touched only the fibrous cover and did not come into contact with the rough lateral or posterior surface. Recovery was perfect 11 days after the operation. The regeneration of osseous tissues can be well studied in such cases by the skiagraph.

Foci of the same character are sometimes formed in typhoid fever. They must be treated after the same principles.

134. In diagnosing inflammatory processes in the joints great difficulties are sometimes offered. As stated before, in the case of *acute rheumatism* the integrity of the articular outlines are well marked. The same applies to acute inflammatory processes due to infection. In the latter event the distension of the joint by the serous or purulent effusion may be represented by the skiagraph.

In *chronic rheumatic processes* the articular bone line appears somewhat irregular.

In *arthritis* the contours of the bone epiphyses appear

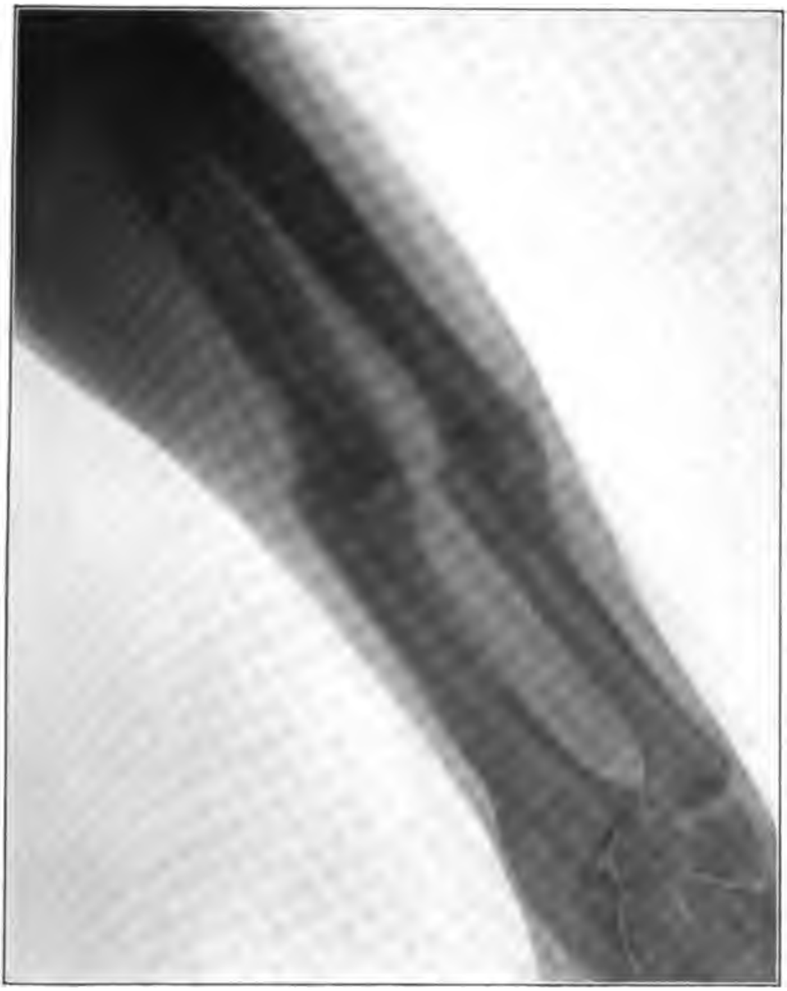

PLATE XXXII.

Deformed Union After Fracture of Radius and Ulna.

3905

irregular; they appear like indentations on some portions, while others are veiled.

In *arthritis deformans* the osteitic proliferations are especially abundant and are well represented by the rays. The arthritic deposits are recognizable as light shades of the deformed epiphyses, as they consist of translucent uric-acid salts, while their periphery is distinguished by a dark sphere.

Plate XXXIX illustrates the case of a laborer of 50 years who sustained an injury of his elbow 11 years before. He reported that recovery took place after several months and that the elbow had remained stiff ever since. During the last few years inflammatory signs had manifested themselves, which were regarded rheumatic. No other joints were involved. Since then he also had repeated attacks of pain in the elbow-joint. When we examined the patient for the first time we found the elbow very much thickened and fixed at a sharp angle. Pressure below the external condyle caused intense pain. Crepitus, so often found in old arthritic processes, could not be produced in this instance as the joint permitted no motion at all. There were no indications of tuberculosis, syphilis, or gonorrhea.

The skiagraph, Plate XXXIX, revealed the presence of malunion (sideward displacement) of the coronoid process of the ulna, which probably had given the first impetus for the development of the arthritis deformans, which is especially well marked in the external condyle of the humerus. The left condyle shows synosteosis with the olecranon. Removal of the projecting fragment by the chisel, separation of the adhesions, and the partial resection of the external condyle, the seat of predilection for the acute attacks, were advised as therapeutic means.

135. Arthropathia Tabica.—In arthropathia tabica the bone appears eroded as in osteoperiostitis, but at the same time it is considerably distended.

136. Tuberculosis of the Bones and Joints.—In *tuberculosis of the bones and joints* the Roentgen rays not only give information as to the seat and extent of the tubercular areas, but also offer the only means sometimes of differentiation from other affections, the clinical signs of which resemble it. The walls of an intraosseous focus appear thickened. Some portions are translucent and their contours irregular. The articular outlines of a tubercular joint have lost their regularity and appear diffuse, cloudy, and sometimes shaggy (Plate XVII).

In later stages, when cheesy foci have formed, for instance, their areas become translucent. The cortex is sometimes entirely destroyed and leaves the impression of having been scooped out with a gouge. When there is calcareous degeneration the foci appear dark shaded.

In the case of extensive tubercular destruction the eroded and displaced cartilages can be studied. In tubercular coxitis the spontaneous upward dislocation of the femur and the separation of its head in the acetabulum can also be easily recognized.

It need not be said that the early detection of a tubercular focus enables the surgeon to do a conservative operation, while at the late stage of extensive destruction such efforts are futile, as it is sadly illustrated by skiagraphic examination.

137. By realizing that so-called *osteosarcoma* is the most frequent of morbid osseous growths, and that of all tumors, sarcoma offers the gravest prognosis, the importance of a thorough diagnosis need not be emphasized. The matrix of osteosarcoma, like that of all osseous growths, is either the periosteum or the medulla in combination with the tissue originating from their proliferation.

Periosteal sarcoma is of moderate hardness and contains either round, spindle, or polymorphous cells. It attaches itself to the bone laterally, but may in its further development encircle it entirely. Periosteal sarcoma may become a real osteosarcoma at a later stage, when osseous trabeculæ are formed.

The skiagraph of periosteal sarcoma is characteristic, since it shows fine spiculated trabeculæ that radiate from the surface. Periosteal sarcoma spreads rapidly and is highly malignant. Whenever the diagnosis *periosteal sarcoma* is made, amputation should be insisted on.

138. Various Classes of Myelogenous Sarcoma. Sarcoma originating from the medulla is called myelogenous and is of a less malignant character. It may be classified as *soft*, *hard*, *alveolar*, and *multiple*.

139. Soft Myelogenous Sarcoma.—The soft myelogenous variety shows the ordinary sarcomatous texture. Its predominating feature is the presence of round cells. It has a decidedly more benign character than the periosteal type. Therefore, it justifies a conservative attempt, that is, extensive extirpation. It produces carious destruction of the spongy portion, which may cause spontaneous fracture. At a later stage the osseous shell will yield to the spreading sarcomatous tissue.

This variety has a predilection for the long bones, especially their ends, and predominates at the lower epiphyses of the femur, tibia, humerus, and radius. Skiagraphs of the soft myelogenous variety show the absence of osseous tissue, small fragments of which are sometimes left here and there.

In the case of a woman, age 28 years, who had fallen on her hand when it was in dorsal flexion, the faint outlines of bone-shell in a soft myelosarcoma were shown. The swelling resulting from the injury produced the impression that a fracture of the carpal end of the radius was sustained.

Three months after the injury, when the patient came under our observation for the first time, a slight deformity was noticed just as it is observed in a badly united fracture of the carpal end of the radius. But the consistency of the epiphysial end was soft. The skiagraph failed to show the evidence of bone tissue, only one small remnant being left at the outer aspect of the radius. Resection was advised, but before the patient submitted to it another month had elapsed, during which time the neoplasm had grown to a great extent. The result was reported as being fair 8 months after the operation.

140. Hard Myelogenous Sarcoma.—The hard myelogenous variety, generally called *endosteal*, or *central*, sarcoma, also shows the ordinary sarcomatous structure. Its distinguishing feature is its fibrous texture and the presence of spindle cells. Some portions contain various tissues; the spindle-cell tissues often containing giant cells. If smaller or larger bone trabeculæ are produced, it is called *osteosarcoma proper;* if there are calcareous deposits, *petrifying sarcoma;* and if the tissues become vascular, a *telangiectatic sarcoma* will be formed, so that it may be mistaken for an aneurism.

In later stages, when there is a regressive metamorphosis, fatty or cystic degeneration may take place. Then these neoplasms that occur, especially in the femur, tibia, and inferior maxilla, may attain an enormous size.

The skiagraph of osteosarcoma proper shows more osseous tissue than the former variety, but its outlines are very irregular. Osteosarcoma proper usually commences near the epiphysis of a long bone.

The skiagraph of an osteosarcoma proper in a woman, age 40 years, showed the destruction of the lower third of the radius and of a large portion of the carpus. Resection was performed; the result was perfect, as was illustrated by another skiagraph taken more than 4 years after the operation, which showed the regeneration of the osseous tissue.

141. Alveolar Myelogenous Sarcoma.—The alveolar variety is characterized by its alveolar stroma, which contains nests of large cells. They have a predilection for the bones of the skull and the trunk.

142. Multiple Myelogenous Sarcoma.—The multiple variety (also called *myeloma*) is characterized by the presence of numerous whitish foci, which consist of small, round cells. It has the same structure as the lymphoid sarcoma and is almost exclusively found in very old individuals, for whose skull and trunk they show the same predilection as the former variety.

The skiagraph of the alveolar, as well as the multiple type, shows the foci as light irregular shades. The structure of their type, especially their manner of destroying the preexisting bone-tissues, the thin osseous walls, and the trabeculæ formation, is the standpoint for their skiagraphic study. The intra-osseous tension is responsible for the expansion of the compact osseous layer, which is thus made gradually weaker and at last almost entirely disappears. Thus, we see that it is the abnormal and

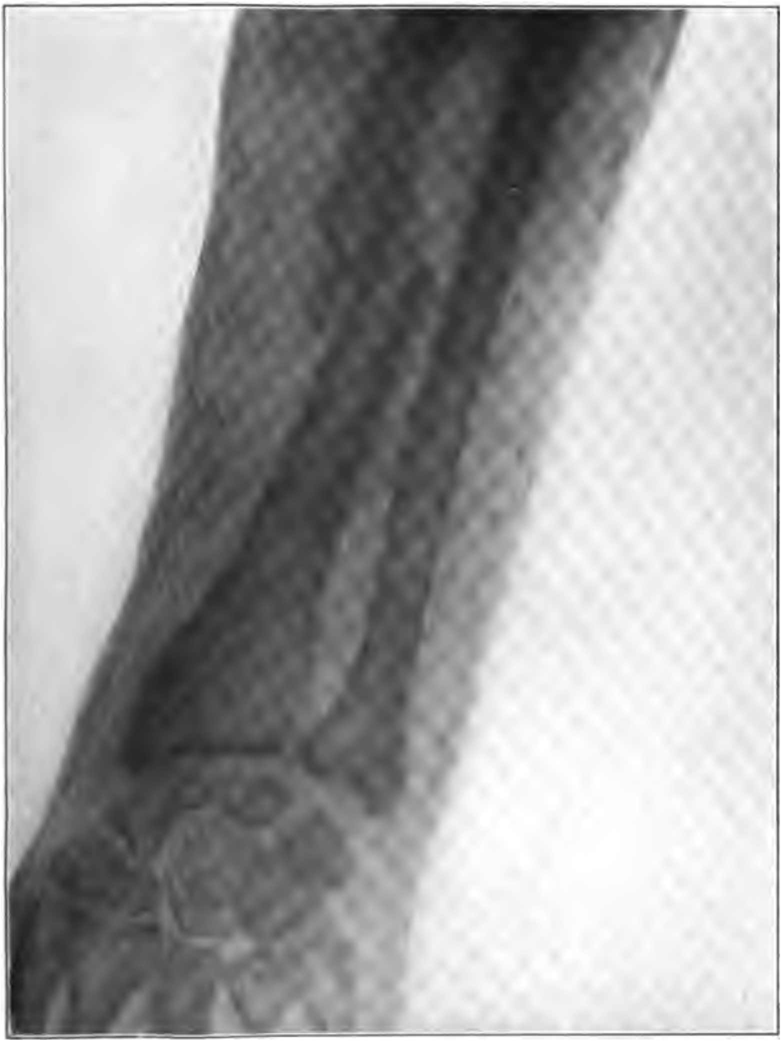

PLATE XXXIII.

Fracture of the Shaft of the Radius, Showing Imperfect Reduction Through Plaster-of-Paris Dressing.

indefinite outline, or even the entire absence of osseous cells, the cortex especially disappearing, which is more or less characteristic of the various types of osteosarcoma in contradistinction to other bone diseases.

As to differentiation it may be said that in aneurism the bone would show intact. Attention was called to the usefulness of the Roentgen rays in a case of femoral aneurism, which, on account of extremely thick walls, showed no pulsation, so that it had originally been taken for osteosarcoma, an amputation, then, having been considered. The femur appearing intact, it was evident that there was a disease of the soft tissues.

143. **Osteoperiostitis.**—In chronic osteoperiostitis the walls appear irregular, but the irregularity is one-sided and there is a globular or spindle-like shape. In tuberculosis the shade will be cloudy or shaggy. In osteomyelitis the cortex shows nearly normal outlines.

144. **Syphilis.**—The skiagraphic expression of syphilis is also characteristic. In the congenital form large ossified areas are recognized in the epiphyses that would appear translucent in their normal cartilaginous condition. On the other hand, light areas are noted in the diaphyses as an expression of insufficient calcareous deposition. The synosteosis between the cartilaginous epiphyses and the diaphysial end appears as a very marked line, indicating the abundance of calcareous salts deposited there. Gummata show regular light shaded foci. Their disappearance after the administration of iodid of potash confirms the diagnosis.

145. **Osseous Cyst.**—Osseous cyst, showing the same clinical signs as osteosarcoma, may easily be confounded with it. But in osseous cyst, while there is the same bulging as in osteosarcoma, the line of the cortex, on account of its thinness, appears narrow, but well marked and regular. The fluid center of osseous cyst renders the skiagraph translucent, the light shade showing the same regularity. The adjacent epiphyses are also normal in osseous cysts. The treatment of

these various affections being different, the importance of a correct diagnosis is evident.

Osteomyelitis, necrosis, tuberculosis, syphilis, and osseous cyst demand conservative measures, while sarcoma calls for the most radical treatment.

The grave prognosis of sarcoma arms the surgeon against any feeling of sentimentality. Under such fatal circumstances he may not shrink from advising one of the most mutilating operations, because he knows that otherwise not only a limb, but also life will surely be lost.

On the other hand, how painful must it be for a surgeon to find that because of his error of diagnosis such radical steps have been taken unnecessarily; that, in other words, an extremity may have been amputated where only an osseous cyst existed, which could have been cured by simple incision.

It is indeed not very difficult to confound the two diseases. As emphasized in Art. **137,** osseous cysts resemble osteosarcoma in its slow, painless onset, often preceded by an injury; in the gradual bulging of the area involved; and in its preference for youthful age and the long bones. These being characteristic features of osteosarcoma, as well as of osseous cyst, it is evident that the differential diagnosis cannot be made by considering the history, nor by inspection, nor by palpation.

The fact that the interior of an osseous cyst is filled with opaque bloody serum and that its walls are lined with a smooth coat, while in osteosarcoma solid masses are formed, indicates that an exploratory incision combined with microscopical examination would clear the question of diagnosis.

But the Roentgen rays give us more valuable information than the exploratory incision itself, and for the patient a Roentgen ray exposure is certainly more agreeable than an exploratory incision. Should an operation be decided upon, the microscopic examination can then be made.

At the early stage, osseous cysts, be they at the tibia or at the femur, are easily overlooked, the symptoms being insignificant. Sometimes there is a very slight pain that comes and goes. The joints are freely movable, and neither inspection nor palpation reveals any abnormality. After several months have elapsed, the circumference of the extremity may appear very slightly enlarged, but it may not be before a fall on the thin shells of the cortex has produced a fracture that the symptoms are fully appreciated.

146. **Osteoma.**—Other osseous diseases, like osteoma, osteomalacia, and chondroma, also offer some skiagraphic peculiarities in proportion to their various textures. Osteoma, of course, shows the shape of the osseous deformity, but there is a normal architectonic structure.

147. **Osteomalacia.**—On account of the dissolution of the calcareous salts, osteomalacia is distinguished by the absence of an osseous shade. In contradistinction to osteosarcoma the whole bone appears translucent. In *chondroma* there is a regular light shaded area according to its cartilaginous character.

148. **Acromegaly.**—In acromegaly the phalanges of the head are broader than normal and show no osteophytes, while their epiphysial ends are thickened. The long bones appear straighter and broader than normal. Some of the carpal as well as of the tarsal bones are distinguished by the presence of exostoses.

149. In *myxedema* the epiphysial lines of the long bones show premature synosteosis.

150. In *syringomyelia* the epiphyses of the long bone are hypertrophied and show rich osseous proliferations, which, however, contain but few calcareous salts.

151. The changes in *rachitis* on account of the absence of calcareous deposits are characteristic. They resemble those of osteomalacia, from which rachitis is distinguished by the irregular arrangement of interspersed osseous structures as well as by the deformed shape of the bones.

152. In *cretinism* similar conditions are found, the epiphyses being nearly invisible while the diaphyses only show distinctly.

153. **Raynaud's Disease.**—A peculiar condition of the bones was discovered in Raynaud's disease. A woman of 40 years, who had been well until 14 years ago, noticed a slight pain in the index finger of the left hand. At the same time she noticed a marked pallor of the whole finger. Four months after the sudden onset of the pain repeated congestion was observed in the region of the second and third phalanges of the same finger, which continued until about 6 months after the onset of the first symptoms, the tip of the finger becoming dry and black. Amputation was then performed. The patient regained and kept her health until 6 months ago, when the same pain and pallor extended symmetrically over both hands.

When the patient was seen for the first time a great pallor of the third, fourth, and fifth fingers of the left hand and of the little finger of the right hand was noticed. The second, third, and fourth right-hand fingers were moderately anemic. Sometimes the color changed into a cyanosed appearance.

Both hands were very cold, just like true gangrene. No other parts of the body were affected. There was no fever. The examination of the urine was negative. The patient did not seem to be hysterical, but apparently suffered intense pain sometimes.

The skiagraph showed atrophy of the upper end of the third phalanges (second phalanges of the thumbs) and osseous proliferation at the upper end of all second phalanges (first of thumbs). The third phalanges appeared triangular and resembled claws.

A similar condition was found in a feeble man, age 30 years, who, at the present time, has fully recovered. The onset took place in the toes of his right foot, gangrene of the whole foot becoming complete 2 months afterwards, so that Syme's amputation was performed. Skiagraphs taken of the foot before and after operation showed nothing abnormal. But 1 year later the disease commenced in both hands to a moderate degree. The fingers were covered with cold sweat and red and blue patches sometimes. The tip of the left index finger together with the upper end of the third phalanx became gangrenous. The patient was treated with arsenic and local gentle massage. The nutrition of the bone is much more disturbed by this sphynx-like vasomotor lesion, than is assumed. It would be

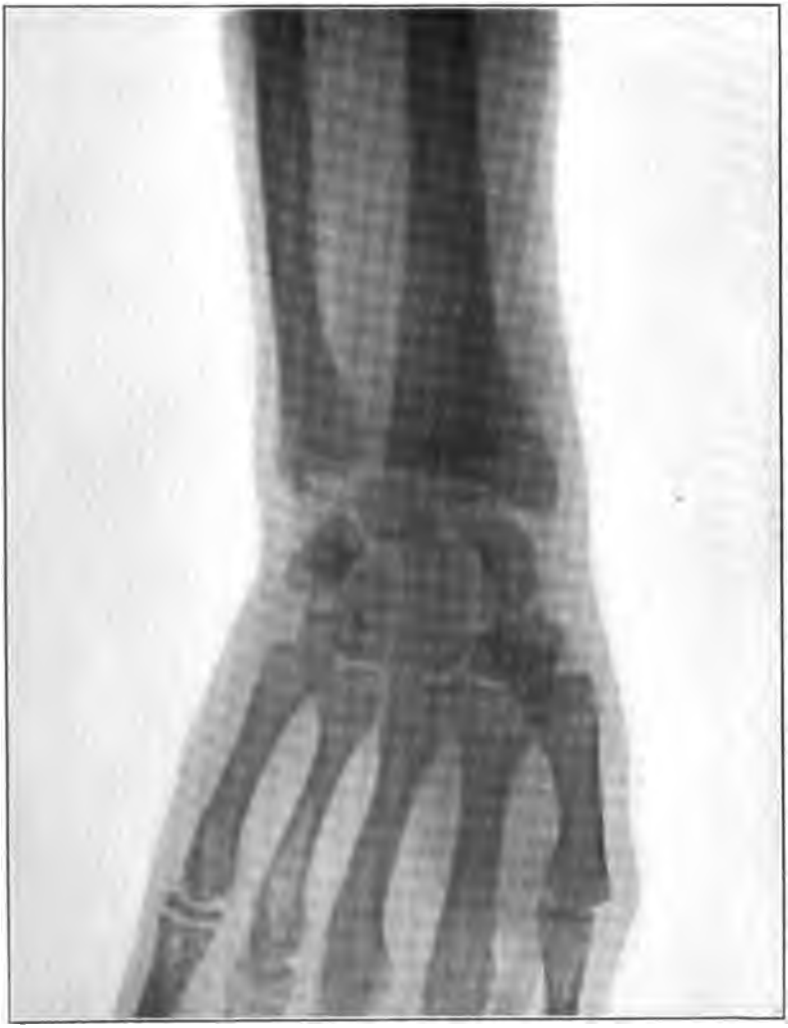

PLATE XXXIV.

Osteoepiphysial Separation of Carpal End of Radius.

well worth while to study these phenomena more extensively. The skiagraphic characteristics described, however, are not expected to serve as substitutes for our well-tested clinical methods of diagnosis, but should be regarded as a valuable adjunct in general, and sometimes as a determining factor in doubtful cases.

THERAPEUTIC VALUE OF ROENTGEN RAYS.*

154. Soon after the utilization of Roentgen's discovery reports of extensive dermatitis and gangrene of the integument were published, which disturbed the public mind in a deplorable and unjustifiable manner. But, especially since the time of exposure is now so much shorter than during the earlier stages of the art, the possibility of originating skin irritation is extremely small.

It is undeniable that a peculiar trophoneurotic idiosyncrasy exists in a few individuals, but in the great majority of known cases the burns of the skin were caused by the lack of knowledge of the unskilful operator, the tube often being too near the subject, or by too prolonged and too often repeated exposures. Such accidents are not surprising, so long as laymen, such as opticians and instrument makers, who understand nothing of the anatomy and physiology of the skin, are entrusted with the "manufacture of skiagraphs."

155. The question of proper dosage must be perfectly understood by the operator. A person, for instance, that irradiates a patient suffering from some skin affection every day intensely for a whole hour, irrespective of the reaction following such a radical procedure, so that gangrene occurs, has just as little business to do skiagraphic work as a shoemaker has to prescribe morphin.

Since February, 1896, we have made nearly 4,000 skiagraphs, and have never observed the slightest irritation of the skin in any case in which the rays were used for diagnostic

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*See also Therapeutics of Roentgen Rays in *Electricity in Surgery*.

purposes, except lately when we experimented with very powerful tubes. A very stout man, who after having suffered from pyothorax for more than 2 years and who still presented an open cavity, was irradiated for the purpose of determining the extent of rib-resection performed previously. The pleuræ had become very much thickened, which explained the difficulty of penetration. Nine exposures had to be made in short succession until a satisfactory plate was obtained. One week after the last exposure dermatitis of the irradiated area set in, from which the patient did not seem to suffer much. In fact, he took the itching sensation felt as one of the many annoyances of regular wound treatment. The therapy consisted in the application of boro-salicylic solution during the acute stage, which lasted 5 days. When the epidermis began to peal off, dermatol was dusted on the surface. Recovery was perfect after 3 weeks. The scar is still noticeable, after 3 months.

With the ordinary tubes two cases of circumscribed depilation were observed. In both patients the skull had to be skiagraphed frequently and at short intervals. In one case depilation began after the fifth, and the other after the sixth, exposure, and in both instances the hair was perfectly restored 3 weeks afterwards.

Changes in the pigmentation of the integument or in the growth of the finger nails, congestion, inflammation, and necrosis of the skin are reported. While experimenting with the powerful tubes, which were responsible for the dermatitis described, we observed cessation of perspiration on the dorsal surfaces of our hands, so that we had to stop work entirely for several weeks, when normal conditions were restored again.

To protect the operator it has been advised to use the patient's hands for ascertaining what degree of translucency is shown by the tube. But while this is no doubt the simplest way of self-protection, it is not in accord with the principles and the spirit of the noblest of all professions.

We have suggested the wearing of gloves lined with tin-foil during examination, the hands to be used alternately for ascertaining the degree of translucency. The fluoroscope recently devised by Levy-Dorn also protects the hands of the operator to some extent and can be recommended for that purpose.

Excessive irradiation endangers the hand of the operator. One of the most promising German investigators burned his hands to such an extent that, first, amputation of the index finger and, later on, of the arm was necessary. The victim of science being of poor health at the time, his death from the shock of the operation is explained easily.

156. It was not more than natural that these properties of the rays were soon utilized for therapeutic purposes. Cases of hypertrichosis, or nævus vasculosus, of all the various types of eczema, psoriasis, and sycosis, have been reported as cured by the rays. There can also be no doubt that parasitic skin diseases such as lupus vulgaris and erythema yield to the rays. Sycosis parasitica as well as non-parasitica and favus have been cured after one exposure.

In a case of sycosis parasitica that had existed for 6 years and had resisted the usual methods of treatment, a perfect cure was obtained after an exposure that lasted 7 minutes only.

In a case of lupus of the inguinal region, a perfect result was obtained. After the sixth exposure, inflammation of the lupus area began and the nodules shelled out, together with the destroyed tissue. In their place a light red ulcus remained that bled at the slightest touch and which did not cicatrize until 9 months after the last exposure. In such cases transplantation is generally indicated. It goes without saying that this mode of treatment, while most effective, is very annoying to the patient, whose gratitude to the physician is somewhat restricted on that account, even after perfect recovery.

In some of the cases reported the nodules did not shell out, but shrank, presenting the appearance of having been painted with varnish.

157. A great deal, however, can be done to limit the ill consequences of the irradiation treatment of skin diseases, which should not be resorted to unless all other therapeutic measures have been exhausted. Under proper precautions the ill effects of the rays can be avoided. In the first place, the healthy parts in the vicinity of the diseased area should be protected by sheets of tin-foil. Then the patient's subjective condition should be carefully watched. As soon as there is a slight burning sensation or itching within the irradiated sphere, further exposures must be stopped.

158. For therapeutic purposes the tube should be as near the diseased area as possible, and the time of the first exposure should not be longer than 10 minutes. Later on, if no reaction occurs, the irradiation may be kept up for from 20 to 30 minutes. In lupus, as many as fifty exposures may be necessary to destroy the nodules. In obstinate cases exposures may be made daily.

During the intervals the diseased area should be powdered with amylin or dermatol. In the event of relapse, the same treatment must be commenced again.

It is necessary to individualize, just as in other therapeutic indications. Some individuals show signs of irritation after a few exposures, and others do not react until after frequently repeated and intense irradiations.

At first these remarkable results were explained on the theory of bactericidal influence of the rays. But it seems that their effect is of a decidedly electrochemical character, the congestion caused by the irradiation being mainly responsible, just like the artificial hyperemia in tuberculosis. In disturbed nutrition of the skin the inflammatory reaction produced by the rays sets up an alteration in the circulation of the affected spheres.

159. Bacteriologic experiments have shown that the rays, applied directly after inoculation with anthrax bacilli as well as with streptococci and staphlococci, had no effect. But pure cultures of cholera, typhus, and diphtheria died after an exposure of 48 minutes to intense radiation. It seems that various bacteria react differently, according to the quality of the plasma and the degree of the fluid they contain.

160. The good results obtained recently in the treatment of epithelioma induced us to try irradiation in sarcoma. The patient, a strongly built cooper of 36 years, remembers that

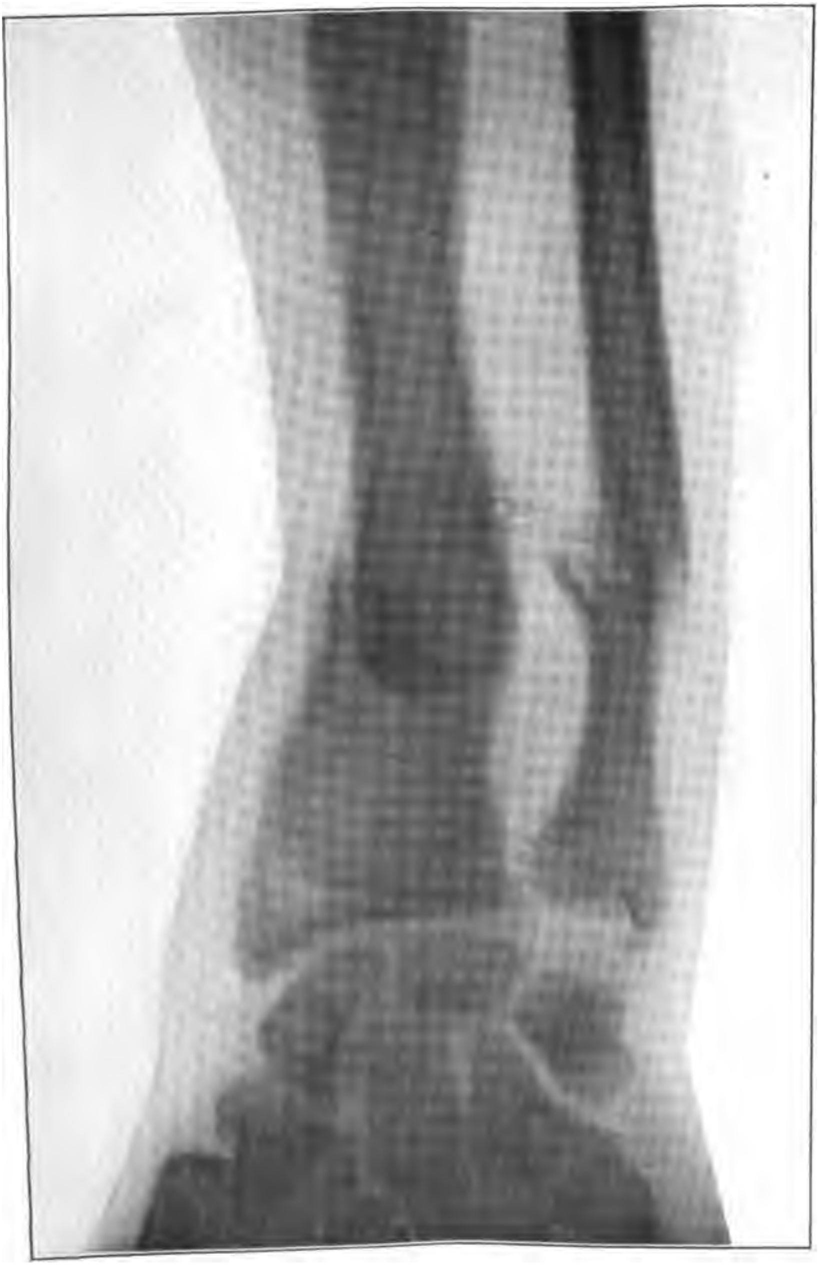

PLATE XXXV.

Fracture of the Lower End of the Radius Combined With Fracture of the Ulna, Showing Deformed Union.

ever since 15 years he observed a small black speck (mole?) at the region of his external malleolus. About 1 year ago it assumed the appearance of a common verruca. A continuous increase in size was observed then. In November, 1900, the "verruca" became sensitive and the surface began to excoriate. Carbolic acid baths were now prescribed by the patient himself and faithfully used, until about Christmas the growth had reached the size of an apple. It was not until then that the patient became afraid and consulted his family physician, who referred him to the St. Mark's Hospital.

On December 24, 1900, he was found in the following condition: The strongly built patient showed a healthy appearance. He admitted being a potator. The family history was good. At the region of his left external malleolus a tumor of the size of an apple was noticeable. Its consistency was moderately hard, its surface of a smoky gray color, and seemed to have originated from the confluence of a number of small warts. It could not be dislodged from its base. The inguinal region contained a gland of the size of a walnut.

At first the diagnosis lymphosarcoma was made and amputation was proposed, but the patient refused to submit to it. His family also being adverse to such radical steps, we contented ourselves with extirpation of the tumor and of the inguinal gland. The apparently healthy periosteum of the externe malleolus was removed together with the neoplasm. Recovery being perfect in a few days, the patient left the hospital.

Microscopical examination of the growth revealed the presence of pigment that proved that we had to deal with melanosarcoma, the most malignant type of sarcoma. The patient returned to the hospital 6 weeks afterwards. The same tumor showed at the outer malleolus again, but it was somewhat broader and flattened. Its margin was encircled by a few bluish-black nodules of the size of a pea, which could be compared with hemorrhoidal nodules. A glandular convolution of the size of a goose egg had developed in the inguinal region in the meanwhile. Extirpation was performed again. The patient withdrew from treatment 2 weeks afterwards, his excuse being that he felt perfectly well again. Four weeks thereafter he presented himself again with a relapse. This time there were about 30 dark bluish-black grape-like nodules of various sizes. The larger nodules bled easily on touch. The inguinal region showed a tumor of the size of the head of a new born child. At the inner surface of the leg, especially alongside the inner border line of the calf, several dozens of nodules had originated that closely resembled those of the tumor itself. Their size varied between that of a head of a pin and a cherry. Extirpation was done once more. The microscopical examination of the removed portions showed the alveolar character and deposits of pigment in the large cell-nests as well as in the small cells of the supporting tissue. One of the specimens was colorized with hematoxylin and esin and a second with van Giesons' fluid.

The patient would not have submitted to amputation, but regarding the metastasis in the inguinal region, the prospects of such an operation at this late stage would not have been promising. Serum-treatment was now considered first. Although we had never experienced any benefit in a fairly large number of malignant cases, still we regarded its use justifiable in such desperate cases. But at the same time the thought of Roentgentherapy suggested itself to us. The excellent results obtained in lupus and other skin affections by Albers-Schoenberg, Hahn, Schiff, Freund, Ziemasen, Kümmell, Muehsam, Holland, Schenkel, Jutassy, and Neisser, could also be corroborated by us (see Irrtuemer der Roentgenographie, Deutsche Medicinalzeitung, 600, No. 51, and Fractures, With an Appendix on the Practical Use of the Roentgen Rays, Philadelphia, 1900). In epithelioma of the lower eyelid and of the cheek we obtained a perfect result after a few exposures only. Without entertaining audacious hopes we began to irradiate the defect left after the last extirpation. The time of exposure was at first 10, then 20 and 30, and at last 45 minutes. When the exposure lasted 45 minutes the patient felt an itching sensation over the whole leg, which lasted for several hours. Irradiation was done 7 times. At the end of 6 weeks not only was there no trace of a relapse, but a number of the metastatic nodules of the calf, especially those near the area of the irradiation, had disappeared; some others had shrunk.

The inguinal tumor became larger during the time of this treatment. It is our intention to remove it again and to irradiate the wound area left as soon as there is a possibility.

As mentioned before we are far from indulging in adventurous hopes. But such experiments are justifiable in so desperate a case, even if they should be without any result. But the fact cannot be denied that in great contrast to the former course after preceding extirpations, no relapse was observed, and what is still more interesting, well developed sarcomatous tissue shrank and *cicatrized.* This proves the influence of the rays beyond doubt. How far this influence goes, however, is not demonstrated by this observation and further experiments have to clear that up.

161. We venture to call attention to the fact that since Heidenhain proved the existence of carcinoma cells below the fascia in carcinoma mammæ, surgery has drawn the practical conclusion that the pectoralis major muscle—or at least its superficial stratum—must be removed, since no surgeon at the present time would expect recovery from the mere extirpation of those cancerous portions that are microscopically visible.

If the carcinoma cells have advanced so far that they have ceased to be accessible to the scalpel, speedy relapse can surely be expected. Now, if we had a means that would, after thorough removal, penetrate the deeper strata so that those carcinoma cells that are situated beyond the reach of the knife would still be attacked by it, and perhaps destroyed, or at least arrested in their further development, the question of the therapy of cancer would be solved.

If the parasitic nature of carcinoma will be proved some day, the effect of an antiparasitic medium can be easily understood. The Roentgen rays possess antiparasitic properties to a certain extent. Their therapeutic significance is still sphynx-like. But it can safely be maintained that their effect is sui generis and cannot be compared with that of Paquelin's cautery or of the obligate mustard plaster.

These views may, it seems to us, be applied to the sarcoma question. The danger of burning the patient is not small under such powerful treatment. While experimenting, other parts of the body must be protected with tin-foil and the operator himself should wear gloves lined with tin-foil. The danger of Roentgen ray dermatitis, however, should not have great weight in a malignant case. For the poor therapeutic results reported by some investigators the fear of using a strong current may be held responsible. If a strong effect is desired, intense irradiation must naturally be used. The patient, of course, should be informed about the risk.

In revising this report 3 weeks after the demonstration, the defect at the outer aspect of the malleolus was perfectly cicatrized. After 9 weeks no relapse had been observed. The inguinal tumor was removed on the day after the demonstration, as intended, and now the inguinal area is also irradiated. The disease had reached a stage in which final recovery can hardly be expected, and it is to be regretted that the thought of Roentgentherapy did not suggest itself at an earlier period. Further reports on the fate of the patient are reserved.

FALSE INTERPRETATIONS OF THE ROENTGEN RAYS.

ITS MEDICOLEGAL ASPECTS.

162. The ease with which some of the small bones of the human body can be reproduced by the rays on a photographic plate led many medical novices, and even laymen, to the indiscriminate use, or rather abuse, of the new discovery. It is little wonder that the results of such an abuse of the rays were soon heralded and misapplied by officious friends, inconsiderate confrères, and last, but not least, by certain members of the legal profession.

In order to avoid errors, it should never be forgotten that a so-called Roentgen ray picture is by no means an ordinary photograph of an object, but only a silhouette (skiagraph),

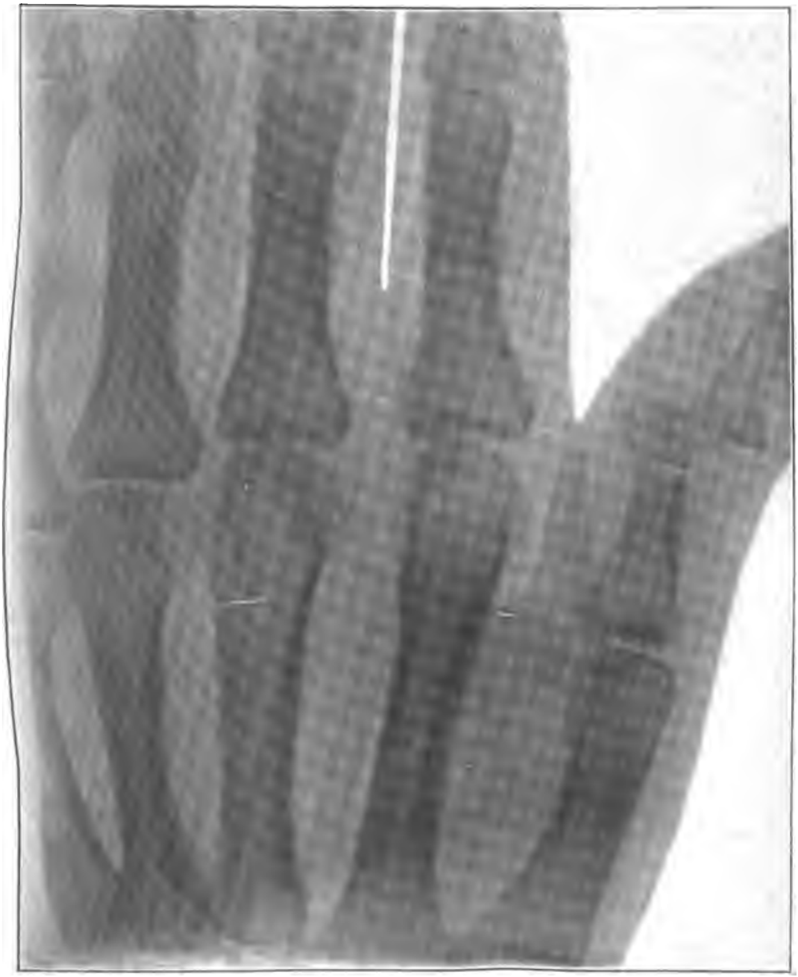

PLATE XXXVI.

Dorsal Dislocation of Thumb.

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that is, a photograph of its shadow. To interpret such shadows properly, a thorough knowledge is required of the normal anatomical relations of the tissues, especially of the bones that produce such shadows. As the most minute gradation of density is registered, it is important to be thoroughly acquainted with the anatomical relations of the bones producing the doubtful shadow. The questiŏn, then, will be whether the supposed shadow is normal or not. On certain portions of the skeleton the muscles and tendons will naturally cause obscure shadows. The carpus is especially prone to produce such errors in the skiagraph; the tuberosities of the trapezium, the scaphoid, the hamulus ossis hamati, the os pisiforme, and the eminentiæ carpi volaris, radialis, and ulnaris double up the thickness of the carpus, thereby causing dark shadows that might be mistaken for foreign bodies. Similar considerations and similar cautions apply to other diagnostic opportunities offered by the rays.

163. Projection Plane.—If a skiagraph of the human hand, for instance, is taken, the plate will show the least light where the bones rest, while the soft tissues appear opaque. There is also a difference of opacity according to the thickness of the tissues, their blood-supply, and their air capacity. The foot, while easily skiagraphed in the direction of the dorsum toward the planta pedis, from the toes to the upper third of the metatarsus, presents an obstacle farther backward in the first and third cuneiform bones and the scaphoid, so that it is necessary, also, to skiagraph the foot on these portions transversely by having the outer surface rest on the support. It is by this procedure only that the isolated shadows of the astragalus, the calcaneum, the os cuboidum, the scaphoid, and the fourth and fifth metatarsal bones can be distinctly outlined, so that false interpretations may be excluded. In the early era of the Roentgen rays, the normal sesamoids were, also, sometimes incorrectly interpreted.

How important the knowledge of minute anatomic details is, especially of non-pathological abnormalities, will be evident from the fact that the os intermedium cruris (os trigonum tarsi) has been mistaken for a fragment severed from the astragalus.

164. It should also be borne in mind that the significance of a skiagraph for the purpose of estimating the *degree of functional disability* is not always conclusive. A skiagraph may show a considerable degree of bony deformity after a fracture, and still the function may hardly be disturbed. Skiagraphic test has shown that, as a whole, even our best functional results do not always show ideal union. An unscrupulous patient that secures possession of a skiagraph of his own case, which shows considerable deformity, may, although there is no functional disturbance, strongly appeal to a jury on the strength of his skiagraph, if he succeeds in simulating great impairment. On the other hand, there may be but little evidence of bone injury on the skiagraph, but there may be severe impairment of function on account of the injury of the soft tissues (circulatory, trophic, or inflammatory disturbances) that can be represented only faintly, if at all. This shows the necessity of considering all the clinical symptoms in connection with the skiagraph.

165. While it is easy even for a layman to understand the significance of most skiagraphs, there are, as has been mentioned, injuries, the correct interpretation of which presupposes, besides thorough anatomic knowledge, the greatest care and a vast amount of experience as to the different modes of delineation in various projection planes.

The greatest diagnostic difficulties are offered by the joints. The more complicated the joint is, the more complicated, naturally, will the skiagraphs of its various positions appear. It is especially the elbow-joint and hip-joint that are kept in view. First of all, the interpretation of the displacement caused by supracondylar fracture of the humerus and the deformities resulting from it later on may tax the power of discrimination considerably. The older the fracture, the less conspicuous the fracture line will appear. In old fractures the lines cannot be represented as such, and it is only in the case of a union in a displaced position that its features can be guessed. In the case of a woman, age 70 years, for instance, a second skiagraph taken 5 years after a supramalleolar fracture was sustained showed essentially the same features as the first, which had been taken 4 weeks after the injury, because of the marked displacement of the fragments.

166. In case of the entire absence of displacement, it is only a very distinct skiagraph that shows the line clearly. It is natural that in such cases there is no skiagraphic evidence after recovery—that is, in 4 to 10 weeks, according to the type of the fracture. Should a court, for instance, doubt, in such an event, that there had been a fracture, the skiagraph taken after such a period might show a negative result, although there surely was a fracture. In some cases, as stated before, a very distinct skiagraph, taken only 2 months after a well-proved fracture, showed no signs of it. Had such a case not been skiagraphed shortly after the injury no evidence of the fracture could have been subsequently obtained. When no displacement exists, only a faint fracture line will show, but the presence even of a small amount of callus leaves no doubt as to the previous existence of a fracture.

On the other hand, callus formation may under extraordinary circumstances be so abundant that, in spite of the absence of displacement, the fullest evidence of fracture may still be furnished after months have elapsed. In one case callus formation was so excessive that the attending physician was accused of malpractice, and it was only the skiagraph that convinced the patient that his physician had treated him correctly, the bones being in perfect apposition, and thus exonerated the practitioner.

167. The intra-articular type of fracture offers the greatest diagnostic difficulties, inasmuch as the fracture line is often obscured by the callus formation. If, however, a skiagraph of the other joint is made at the same time, in the same position, and in the same projection, the various delineations of the shadows will be correctly understood and interpreted.

168. A normal skeleton should also be compared with the skiagraph. It should be particularly remembered that certain pathologic conditions, such as rachitis, for instance, influence the outlines of the bones and may deceptively be supposed to represent a portion of the injury. In such an event a skiagraph of the fellow extremity will set matters right. In very young children the eminentia capitata appears as if entirely severed from the humerus, although the relations are absolutely normal. The explanation of this very important phenomenon is that the epiphysial tissues are not sufficiently ossified to produce a shadow on the plate. If these points are not thoroughly considered a displaced fragment of a fracture might cause an erroneous diagnosis. Union between the epiphysis and diaphysis of the head of the humerus is not perfect before the twentieth year. The lower epiphysis of the humerus consists of four nuclei that ossify between the eighth and seventeenth years. The epiphysis of the trochlea as well as of the olecranon ossify between the seventh and twelfth years, which explains why an osseous nucleus that is still connected with its neighboring epiphysial nuclei and the diaphysis by cartilaginous tissue appears as an isolated piece of bone which might erroneously be mistaken for a fragment. The acromioclavicular junction sometimes shows in the skiagraph a hiatus of the width of a finger so that a diastasis of the joint may be assumed (see Plate XXVI). But since our knowledge of this new subject has increased, we know that this apparent diastasis is by no means pathological and that there is a normal gap between the osseous ends of the acromion and the acromial end of the clavicle. The upper epiphysis and the diaphysis of the radius unite between the seventeenth and the eighteenth year. During the early work with Roentgen rays the translucent space above the epiphysial cartilage in children was erroneously taken for a fracture line. The head of the femur unites with the diaphysis at the eighteenth year, and the lower epiphysis follows after the twentieth year. The upper epiphysis of the tibia unites with the diaphysis in the twentieth or twenty-second year, while the lower tibial epiphysis unites with the diaphysis between the eighteenth and nineteenth years.

169. For the thorough interpretation of skiagraphs in children, it is important to know that at birth the diaphyses

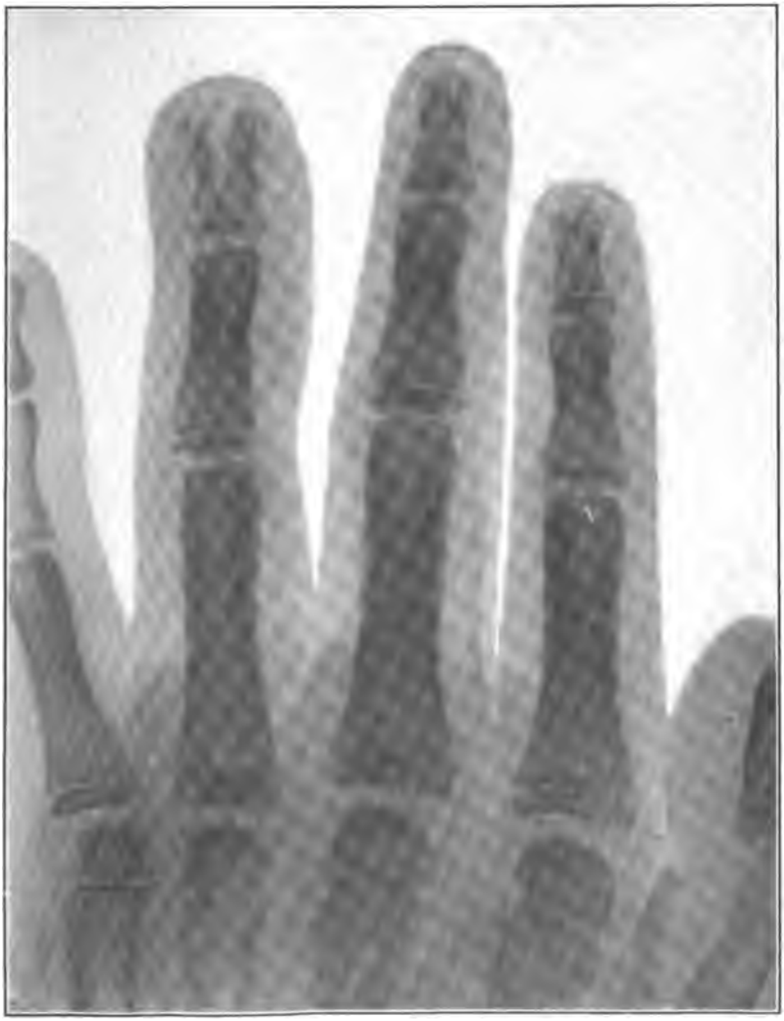

PLATE XXXVII.

Longitudinal Fracture of Third Phalanx of Ring Finger.

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of the radius and ulna are ossified, while their epiphyses as well as the whole carpus are still cartilaginous. It is not before the seventh year that an osseous nucleus shows at the lower epiphysis of the ulna. Union with the diaphysis sometimes begins with the twelfth year, but as a rule not before the fifteenth. Even then a small epiphysial disk remains, which does not disappear before the seventeenth year in the female and not before the nineteenth year in the male.

The osseous nuclei of the carpus show at different periods, viz., at the os capitatum at the fourth month; at the hamatum at the fifth month; while the triquetrum shows its nucleus between the second and third years, the lunatum between the third and fifth, the naviculare between the fifth and the seventh, the trapezium and the trapezoid between the eleventh and the fifteenth year. After 5 years the capitatum, hamatum, and triquetrum have assumed their regular shapes, while the others, with the exception of the pisiform, are perfectly developed at the twelfth year.

The osseous nuclei of the epiphyses of the metacarpal bones show at the second year, their synosteosis with the diaphysis taking place between the twelfth and seventeenth years in the female and at the age of nineteen in the male. The epiphysial nuclei of the phalanges are ossified between the fourth and fifth years, their synosteosis with the diaphysis taking place at the same age as that of the metacarpal bones (from the twelfth to the seventeenth year in the female and between the sixteenth and nineteenth years in the male).

170. Regarding the elbow-joint, it must be considered that an osseous nucleus appears at the medial side of the capitulum humeri between the second and third years, another one in the internal epicondyle at the fifth year, a third in the trochlea between the eleventh and the twelfth year, and soon afterwards a fourth in the external epicondyle. The nucleus of the internal epicondyle unites with the diaphysis between the sixteenth and the twentieth year; but the other three nuclei form a synosteosis among themselves at the seventeenth year and then form the uniform osseous epiphysis, which completes its synosteosis with the diaphysis at about the twentieth year. In the capitulum radii an osseous nucleus appears between the fifth and seventh years, and in the olecranon between the sixth and eighth years, both uniting with the diaphysis between the twentieth and twenty-fifth and between the sixteenth and twentieth years.

171. Regarding the knee-joint, it must be considered that the lower femoral epiphysis contains an osseous nucleus at birth, while the nucleus in the tibial epiphysis shows shortly afterwards. At the fourth year both these epiphyses have completed their development, but they do not unite with the diaphysis before the fifteenth year. Textbooks on anatomy say that union takes place between the seventeenth and the twenty-fourth year, but skiagraphic experience points to an average period of only sixteen. The osseous epiphysial nucleus of the fibula appears between the second and the fifth year and unites with the diaphysis between the eighteenth and the twenty-fifth year; but skiagraphy dates this period earlier, viz., the fifteenth year. The osseous nucleus in the tibial spine appears between the eighth and the tenth year; the epiphysial line between it and the diaphysis disappears at the fifteenth year.

172. As to the bones of the foot, it may be said that the lower epiphyses of the tibia and fibula show their osseous nuclei in the first and second years and unite with the diaphysis between the eighteenth and the twenty-fifth year; according to skiagraphs, as early as before the eighteenth year. The osseous nucleus of the astragalus and calcaneum appears in utero, that of the cuboid shortly before or after birth, that of the cuneiform bones between the first and the fifth year, and that of the os naviculare from the first to the fifth year. The osseous nuclei of the metatarsal bones and of the diaphysis between the sixteenth and the twenty-second year.

173. In elbow-joint fractures occurring in childhood it is necessary therefore to take at least two skiagraphs in different projection planes and to compare them thoroughly with the normal fellow. In a case of a fracture of the femoral head, for instance, the deformity had appeared three times as large as it actually was, on account of inappropriate projection. The degree of shortening of the limb was overestimated accordingly. This shows the necessity of considering the clinical symptoms and data in connection with the skiagraph.

In fractures of childhood it should also be remembered that the process of ossification is influenced by various affections of the bone, as for instance, by rickets.

174. The importance of the question of projection becomes evident when we consider that grave errors may sometimes occur even if all preliminary conditions required for a thorough understanding of the case seem to be fulfilled. This will appear from the experience given of the fracture of the tibia, Art. **84.** If that case had been brought before a jury the expert might there, on the strength of the first skiagraph, have testified in good faith that there was no fracture.

As emphasized previously, this experience teaches the necessity of adopting the principle of always taking at least two skiagraphs in two different positions in all cases of suspected fracture.

175. In taking skiagraphs of foreign bodies it must be considered that their size varies according to the distance from the tube. In oblong bodies great errors as to their extent may be committed. Once we were very much surprised in a case where a fragment of a needle had entered the palm of the hand in a perpendicular direction. The plate, while indicating the presence of the needle, distinctly created the impression that the fragment was only about 2 millimeters in length. When extracted it was found to be more than an inch long, the rays having reached the hand in a perpendicular direction so that the circumference of the fragment was reproduced rather than its length. A side view, of course, would have cleared up the error at once.

176. Misinterpretations have also arisen from unavoidable mechanical and chemical defects causing markings in the photographic plate, the significance of which must be well known to the skiagraphic interpreter. Blemishes may also be produced by spots caused by pus from wounds or by perspiration.

In the location of foreign bodies, especially in the skull, many errors were and are still committed.

For malingerers the Roentgen rays may prove to be, for a time, a protection on account of erroneous interpretation, but they will be shown in their true light when assisted by better anatomical knowledge.

177. Soon after the discovery of the Roentgen rays the courts were in a position to grant damages to patients, especially veteran soldiers, who claimed to have been damaged by bullets and were unjustly rejected by medical experts as malingerers. The presence of a bullet, shown on the photographic plate, cannot be denied, and a patient that harbors a piece of cold metal in any part of his body has, as a rule, a good reason to complain. On the other hand, an impostor who pretends to have been shot and simulates functional disability will be exposed by a distinct skiagraph, which would show the absence of the alleged bullet.

It is still an open question whether the court has a right to censure a surgeon for not having used the Roentgen rays in a suitable case, and, furthermore, whether it can compel a patient in a doubtful bullet or fracture case to submit to an exposure by the rays.

178. A distinct skiagraphic plate will always tell the truth. If accompanied by registration of the details of operation, viz., the source of the current (whether battery, static-machine, or street), the length of spark of the induction-coil, the intensity of the tube, the distance of the platinum disk of the tube from the photographic plate, the position of the object, the kind of plates, and the time of exposure, it will be a valid document intelligible to every expert. And together with the anatomic and clinical knowledge of the expert it should be evidence in court.

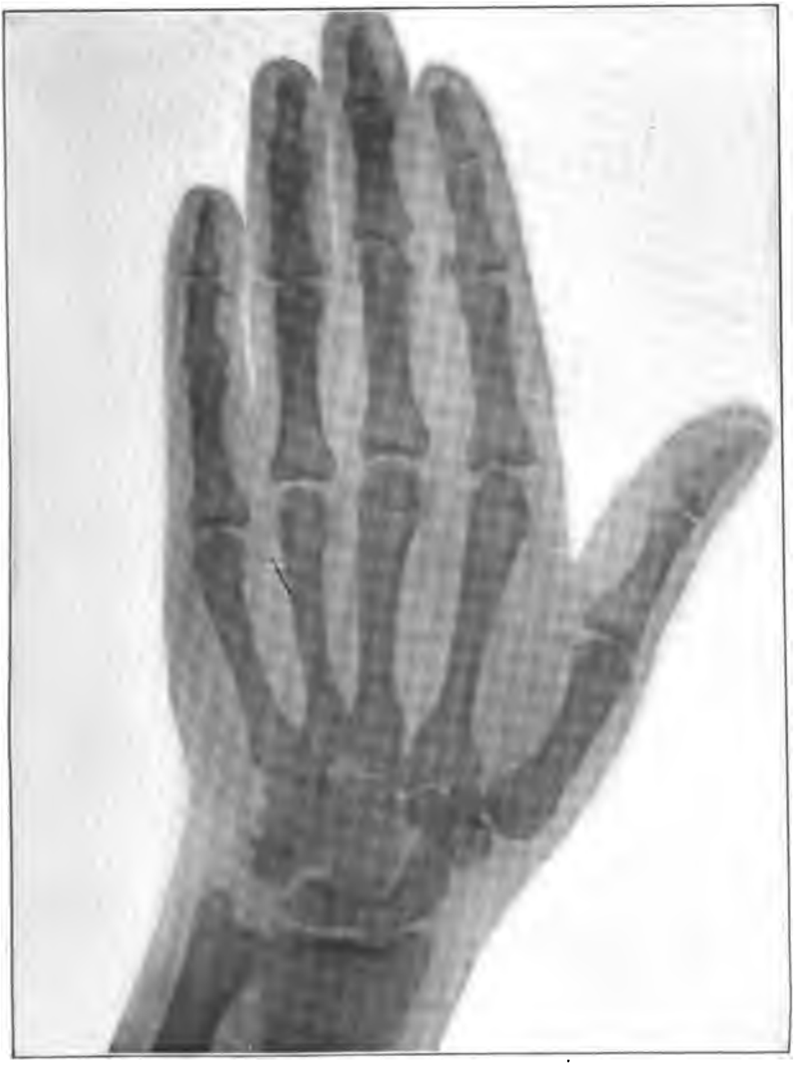

PLATE XXXVIII.

Needle, Showing its Eye, in the Palm of the Hand.

ROENTGEN RAYS IN DENTISTRY.

(EXTRACT FROM *Electricity in Dentistry*, BY LEVITT E. CUSTER, B. S., D. D. S.)

179. The Roentgen rays have no more fitting application than in dentistry. In medicine and surgery their use as an aid in locating foreign bodies has never been questioned, in diagnosing fractures and dislocations, and in detecting the presence of calculi and pus cavities and even the abnormalities of some of the softer tissues whose density differs but little from that with which they are surrounded. The Roentgen rays are also of value in some of the arts, and as the appliances are being perfected and new uses are found for it, its applications are still broadening. The most valuable field, however, will always be in medicine, surgery, and dentistry.

180. While the use of the Roentgen rays in dentistry is not usually in cases in which it is a matter of life and death, as is frequently the case in surgery, its more frequent use will give it a value of a high order. Its dental applications, while confined to a comparatively small portion of the body, are of rather wide range and will require just as much skill on the part of the operator as in work on the thicker tissues. For instance, the dentist must be able to so manipulate his tube and appliance as to differentiate between the roots of the teeth and the bone that surrounds them, a feat equal to any accomplished by the physician. Or, on the other hand, he may have simply the location of a broken broach or a pus cavity, which is comparatively easy. The most frequent dental uses of the Roentgen rays are for locating unerupted teeth, for ascertaining their position and the shape of their roots, for diagnosing fractures of the jaw, for locating foreign objects such as a broken broach, for determining the depth of root filling, the extent of an abscess, or the proportions of the antrum.

181. The successful use of the Roentgen rays requires a somewhat formidable array of appliances, and the manipulation of them calls for one that is accustomed to mechanical details. To this extent the dentist is very well fitted at the very outset by the nature of his mechanical and digital acquirements.

Instruments and instrumentation are his daily company and his occupation. Moreover, Roentgen ray work being an electric process, the majority of dentists are to a large extent familiar with the fundamental electrical requirements and are already equipped with many appliançes that may be used in the work. All things being considered, at the present state of perfection of Roentgen ray appliances, the dentist will obtain the most satisfactory results from the Rhumkorff coil. It is also recommended that he procure one large enough for general work. The city dentist, who is in touch with the general physician or with some established Roentgen ray laboratory, will be most practically profited by the use of an 8-inch or 10-inch coil; but if he expects to derive the most pleasure and benefit from the work he should get a 12-inch or 15-inch coil, for then he will be able to manage all parts of the body. For the country dentist the larger coil is especially recommended, for the reason that the electrical part of his dental office appliances will already form a large part of his equipment, and many physicians will prefer to avail themselves of its use than to take up the work themselves.

182. It is customary in taking a skiagraph to use a plate for large subjects and a film for the smaller. For dental operations the film has especial advantages—it is cheap, convenient to handle, easy to prepare, and is flexible. A cartridge of a 1½-inch film, such as is used in the Brownie camera, will be found to be the most economical, and this can be had at all photographic supply houses. The width of this film is the most convenient; the average dental case can be taken upon a square cut from the end, and if the case calls for a larger piece, it is only necessary to cut off an oblong piece sufficient for the case and place the strip lengthwise.

The plates to be used for larger subjects may be found upon the market. When necessary, ordinary photographic plates may be used for Roentgen ray work with splendid results, but plates especially prepared for Roentgen ray pictures, such as the Cramer or the Carbutt, are to be found. These plates are supplied either in or with light-proof envelopes. We have found that the Cramer Crown brand of plates gives the best results, almost as good as those plates that are especially prepared for Roentgen ray work.

183. The next step is the providing of a light-proof and, to a certain extent, moisture-proof covering for the film. If the dentist has a good coil and becomes expert in the management of his appliance, he will require but a few seconds for an exposure, and his film may be enclosed in two thicknesses of black paper without danger of light or moisture. The film is placed sensitive side down upon a piece of paper 3″ × 4″, and the edges are turned over upon the back of the film. This is then placed upon another piece of paper somewhat larger than the first and enclosed in the same manner. A little gum paper will prevent the opening of the flaps. The film, thus enclosed, is flexible and neat, and can be easily adapted to any part of the mouth.

184. If the dentist requires a considerable length of time for an exposure, he may enclose his film in black unvulcanized rubber, as suggested by Doctors Van Woert and Price. The film should first be covered with an envelope of tissue paper to prevent adhesion of the rubber to the film and also any injurious effects of the rubber upon the film. The black rubber being quite flexible and adhesive, a piece is cut twice as large as the film. The film is placed upon one half and the other half is turned over upon it and the edges pinched together. This makes a light-proof and moisture-proof covering, and a film protected in this manner may be immersed in the saliva without danger of injury therefrom.

185. Dr. C. E. Kells has suggested the use of a little plate holder. This is made by first taking a modelling compound impression of the coronal and lingual aspect of the teeth to be skiagraphed. A piece of 28-gauge aluminum is attached to the inner side of the compound, and to this the piece of film, protected as previously described, is attached by little clips. The whole is then placed upon the teeth and the patient instructed to close the mouth. There are two advantages in this method. It leaves the operator free to manipulate the instrument and the film can be held more quietly. This method is especially valuable where, by the nature of things, from 30 to 90 seconds are required for a dental skiagraph, but when a large and efficient coil and tube are used and but from 3 to 10 seconds are necessary, the film can be held quiet for that length of time by the assistant.

186. The film having been prepared, the patient is comfortably seated in an ordinary chair with a portable head-rest upon the back. An ordinary chair will be found most convenient for the reason that in taking skiagraphs of the upper jaw it is necessary to place the tube well above the patient to have the rays strike the plate perpendicularly and to get the teeth with the least distortion. For the lower teeth it is only necessary to rest the head well back in the head-rest. In making these adjustments the aim should be to seat the patient in such a position that the film, when in place, will face the tube so that the rays will be received perpendicularly thereon. It should be borne in mind that clearness of definition and correct proportions are lost if the plate is not at right angles with the tube.

187. While there is very little danger of producing a burn upon a patient in taking a dental skiagraph, owing to the shortness of exposure, the tube should nevertheless be placed at least 12 inches from the surface of the face. Although the time of the exposure is lengthened by increasing the distance between the tube and the film, even 15 inches would not be too far, and with an efficient instrument it should never be less than that. It should be borne in mind that the rays emanate from a very small surface and proceed outwards in straight but diverging lines, and the farther the object is stationed from the target, as the point of illumination is sometimes called, the more parallel will the rays be. Every skiagraph is larger than the original, but this disparity becomes less by placing the object at a distance from the tube. Nor are these the only advantages to be derived from operating at a distance from the tube. The patient, always a little timid at first, feels more secure at a greater distance and the operator has more room for manipulation. While a greater distance requires more time,

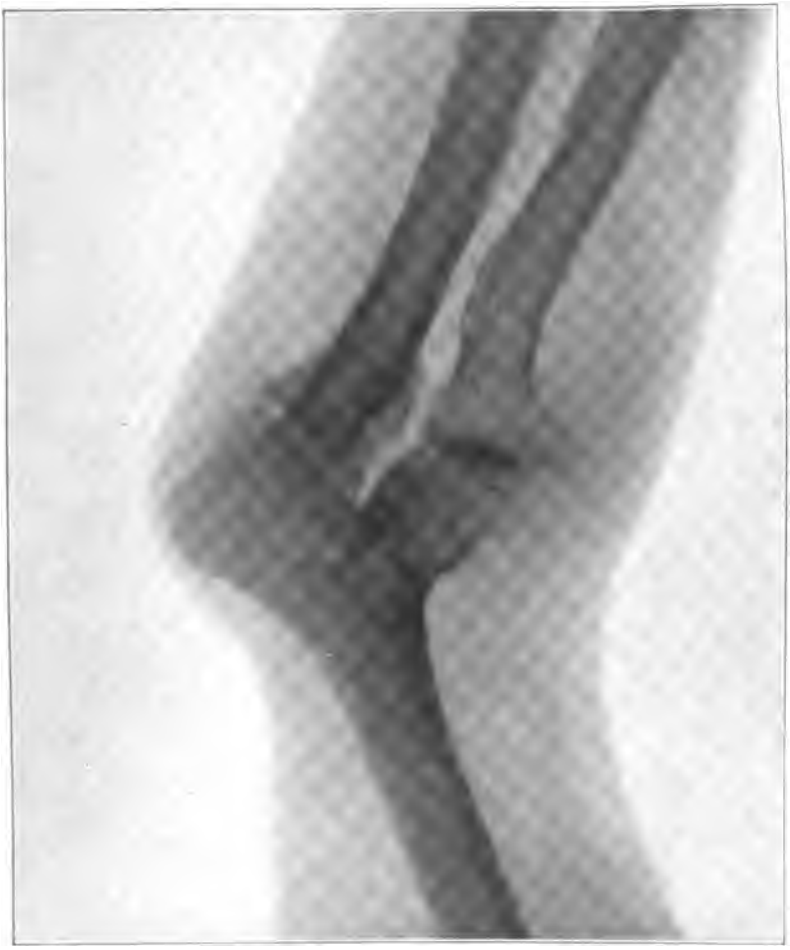

PLATE XXXIX.

Arthritis Deformans After Fracture of the Coronoid Process of the Ulna.

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the dental operations naturally require so little that this may be doubled and yet not be too long. The increase of distance is also compensated for in another way; while it may take a longer time, any movement of the patient is not so largely magnified as it would be if the distance were less. It may be roughly stated that the time required is proportionate to the square of the distance from the tube. If it is found by experiment that with a certain condition of tube it requires 15 seconds at 12 inches from the tube, the operator will find that to get the same result 24 inches from the tube, about 1 minute will be required, and all intervening distances in a proportionate length of time.

It will be found, in practice, that about 15 inches from the target is the proper distance, and having once established a distance it should be kept as nearly as possible thereafter. There are so many variable conditions in the taking of a skiagraph that those that can be fixed should be so.

188. When the distance has been settled upon, the dentist, in determining the length of time, has then to deal with but two variable conditions—the thickness of tissue and the condition of the tube. The thickness of tissue in dental cases does not vary as in general practice, and it is an easy matter to roughly estimate this factor. The following scale of the proportionate length of time, as to the thickness of tissue, may be established. If it is found that 5 seconds, with a certain condition of tube, will give a clear skiagraph of the lower incisors, it will require about 8 seconds for the molars of the lower jaw, and about 15 seconds for the antral region of the upper, and all the other parts at proportional lengths of time.

189. The condition of the tube has much to do with the length of time for an exposure. It will be found that the tube does not always start off at its highest efficiency, and it is this factor that is most variable and that will require the most careful consideration in timing the exposure. This cannot be determined by any standard, and the operator's skill, judgment, and experience are alone to be relied on. During the long exposures on the thicker parts, the physician has an opportunity to watch the tube through the fluoroscope and to judge as to the length of time but the dentist, owing to the short time of most of his exposures, must base his calculations upon the fluorescent appearance of the tube itself. For this reason, it is incidentally mentioned that darkening the room somewhat during the exposure will aid the dentist in judging of the working of the tube.

The tube varies at different times, not only as to the volume of Roentgen rays given off, but as to the condition of the vacuum. The length of the exposure, all other things being equal, has to do with the clearness of the picture, but the variation in the vacuum of the tube has to do with the contrast between the tissues of different density. The effect of tubes of different vacua is a most important consideration in Roentgen ray work, for on this depends almost entirely the securing of a good picture that will show the object or condition most clearly. A tube, for instance, that would best show a broken broach will give but an indistinct outline of the pulp canal or an abscess. Roentgen ray tubes have therefore been classified according to the condition of their vacua into soft, medium, and hard tubes. The soft tube, if used in looking at the hand through the fluoroscope, will show a dark outline of the whole hand, and only by close inspection can the bones be distinguished. This is represented by an external shunt spark of about 2½ inches. The medium vacuum is one that, if observed in the same way, will show the bones with the strongest contrast if compared with the flesh. They appear black, and, on inspection, their minute structure can be very easily seen and studied. The hard tube is one that will show the outline of the flesh and the bones within, but there is not that contrast between the two that was seen in the medium tube. The light seems to penetrate the two almost alike, and because of the loss of contrast, the minute structure of the bone cannot be traced in its finer details, as could be done with the medium vacuum.

190. The rays emanating from a soft tube have little penetrating power, whereas the rays from a hard tube have high penetrating power. For this reason the rays of the soft tube are affected by the least variation of the density of the softer tissues, while those of the hard tube pass through all tissues with but slight change. It should be borne in mind that a photographic plate is more sensitive than the eye, so that in the taking of a skiagraph the vacuum should be much lower than would be necessary for the eye, and it is for this reason that a lower vacuum is used for photography than for viewing the object through the fluoroscope. The vacuum, however, must be high enough, in all cases, for the rays to penetrate the subject. For this reason, also, it will be found that the degree of vacuum should vary somewhat in proportion to the thickness of tissue to be skiagraphed. It will require a little higher vacuum for the arm than for the hand, and a still higher vacuum for the pelvis. There is not only this rising scale of vacuum with increase of density and thickness that must be considered in the taking of every skiagraph, but the more important consideration of proper vacuum for showing the object or tissue at its advantage. The two must be considered together in calculating for the exposure. The physician is constantly dealing with tissues of a wide range of thickness and density, and only by constant practice is he able to successfully take every subject. While the dentist is more fortunate in this regard, because his dental cases are nearly all of the same thickness and density, he, however, has a range of subjects that call for just as fine vacuum calculations. The degree of penetration necessary in dental cases is about equal to that met with by the physician in the case of the hand, so that having once found the proper vacuum for the average dental cases, he has only to vary that slightly to get contrast or penetration. The average condition of vacuum necessary for dental cases will be found in a soft tube and at no time a higher vacuum than a medium tube.

191. There is a great variety of Roentgen ray tubes upon the market, and these are divided into two classes, namely, those with vacuum regulators and those without. The beginner, owing to the many details to be learned, should confine himself to the use of the latter class, for here he is dealing with a fixed vacuum, and that feature of his calculations may be omitted for the time being and taken up later when he is better prepared. The dentist should begin with two tubes, one soft and the other of a medium vacuum. These tubes are not only cheaper, but they will, later on, be useful to him in another way, for in the course of time as their vacua rise by use, these tubes can be used for fluoroscopic examinations and for work upon the thicker parts. Another and very important reason for using tubes with a fixed vacuum for dental purposes is because of the very short time required in these cases. All tubes with regulating devices are at a normally high vacuum, and it takes a few moments of time to "work" them down;, so that, in practice, it will be found that by the time the tube has been brought to a condition of vacuum suitable for a dental case, the film has been exposed long enough and it will be a chance result if the skiagraph is a good one. After the dentist has learned how to manage the tubes with vacuum regulators, he may be able to get the tube in condition and dexterously adjust the patient and film and use the tube before the vacuum rises, but this can never be as satisfactory as a tube with a fixed vacuum and in condition for immediate use.

Physics of Light and Cautery

ELECTRIC HEATING

1. Loss of Electromotive Force.—The phenomena connected with the passage of electric currents through conductors have been treated fully in Volume 1 of this Course. Among the phenomena considered were those relating to chemical decomposition, electromagnetism, induction, and, finally, mechanical effects, as in electric motors.

In every instance, when work was performed in some form or other, the current lost part of its energy by losing part of its electromotive force. In other instances, when no visible work was performed, a certain part of its energy was lost in overcoming the resistance of the electric circuit. An instance of this kind is found in voltaic batteries, where the internal resistance often equals that of the whole external circuit. In this connection it will be remembered that the rule was given in Art. **134,** *Direct Currents*, that "a maximum current is sent through a given external resistance, when the resistance of the battery is equal to the external resistance." It seems that here, and in other similar combinations, a great waste of energy must be going on, and the question naturally suggests itself: What becomes of this electric energy, which apparently disappears without leaving any visible traces behind?

2. Transformation of Energy.—As energy cannot be lost, it must, if disappearing in one form, reappear in some other form, and though the new form in which it reappears is not perhaps at once traceable, it is, nevertheless, present and will be found on closer investigation.

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It is a fact proved by numerous experiments, that whenever a resistance is placed in the path of an electric current, it can overcome the resistance only by giving up part of its energy to the material of said resistance, and that the energy then reappears in the form of heat. As this heating property of the electric current is made use of in cauteries and electric lamps it is important to find the relations between the electric energy expended and the heat developed, when various forms and kinds of conductors are used.

3. Variation in Heating Effects.—In order to fully grasp this subject it is necessary briefly to mention a few facts relating to heat and its effects on different substances. If we take a piece of copper and hold it over the flame of a Bunsen burner for a certain specified time and then measure its temperature, we will find that the latter is very different from the temperature gained by a similar piece of platinum exposed to the same heat and for the same length of time. The latter will show a temperature about three times higher than that of the former. A still greater difference is found if a piece of carbon is heated. Continuing our experiments, we will soon ascertain that metals, fluids, etc. all show a difference in their ability to receive heat from some source or other.

SPECIFIC HEAT

4. We may briefly explain this by supposing that each molecule of matter requires the same amount of heat to raise its temperature a certain number of degrees. The lighter the molecules of which a body is made up the more of them there must be to make up a certain mass. And, further, the greater the amount of molecules a body contains the more heat it will require to raise its temperature. Bodies of higher specific gravity contain a smaller number of molecules in a given mass, because each molecule weighs more. There being fewer molecules to heat, it will require less heat to raise the temperature of the whole mass. We see, then, that there is a close relation between the *thermal capacity* or *specific heat* of a body and its *specific gravity*.

5. Unit of Heat.—It is too indefinite to say that more heat is required to raise the temperature of one piece of metal than that of another piece, and some unit must therefore be adopted to enable us to make a comparison between various quantities of heat. For this purpose that quantity of heat has been selected which is able to raise the temperature of 1 cubic centimeter of water, that is 1 gram, from 3° to 4° C. This unit has been named 1 *calorie.* Five calories will therefore be able to raise the temperature of 1 gram of water 5° C., or 5 grams of water 1° C., and, similarly, any other combination of grams and calories, the product of which will be equal to 5 calories.

6. Table of Specific Heats and Gravities.—In the table below are given the specific heats and specific gravities for various substances. Water is there taken as unity, meaning that if it will take 1 calorie to raise the temperature of 1 cubic centimeter of water 1° C., it will require a fractional part of 1 calorie to raise the temperature of any of the other substances there named to the same height. For instance, lead would require only .0314 calorie, etc.

TABLE I

Substances	Specific Heat	Specific Gravity
Lead	.0314	11.4
Platinum	.0324	22.1
Silver	.0611	10.5
Copper	.1013	8.9
Zinc	.1015	6.9
Iron	.1218	7.8
Graphite	.2018	1.6
Water	1.0000	1.0

7. Relations Between Specific Heat and Specific Gravity.—There is some similarity between thermal and electrostatic capacity. If the latter is small, it requires a small electric charge to raise the pressure to that of 1 volt; and, similarly, if the thermal capacity or specific heat is small, it takes a small amount of heat to raise the temperature 1° C.

In general, it is found that with an increase in specific gravity there follows a decrease of specific heat. Lead and iron are exceptions to this general rule.

An examination of the values given for specific heat will show that it takes twice as much heat to raise 1 pound of silver to the same temperature as that of 1 pound of platinum, and nearly 4 times more heat to raise iron to the same temperature as that of lead. If, for instance, two rods, one of silver and one of platinum, were held together over a Bunsen burner, it would shortly be found that the platinum rod was red hot, while the silver rod would be comparatively cool.

8. The Joule, Watt, and Calorie.—Having now ascertained the meaning of specific heat and a calorie, the relations between the calorie and electrical work have to be found. It was just stated that while an electric current was passing through a conductor the resistance of the latter had the effect of changing part of the electric energy into heat. Heat must, therefore, simply be another form of electric energy, and, as it was possible to express the energy of the electric current in foot-pounds, it should likewise be possible to express the energy of heat in the same unit.

The unit of electrical work is the *joule*, which was found to equal .7373 foot-pound. (See Art. 15, *Direct Currents.*) It has been found that

$$1 \text{ calorie} = 4.2 \text{ joules} = 3.07 \text{ foot-pounds.}$$
$$1 \text{ joule} = .24 \text{ calorie} = .7373 \text{ foot-pounds.}$$

As 1 watt = 1 joule per second and 1 joule = .24 calorie, it follows that 1 watt = .24 calorie per second.

9. Heat Developed in a Conductor Proportional to Square of Current-Strength.—In Art. 20, *Direct Currents*, the following formulas for finding the number of watts developed were given:

$$W = E \times C = \frac{E^2}{R} = C^2 R.$$

The last of these only will be used in finding the relation between the current passing through a conductor and the heat developed in it.

This formula $W = C^2 \times R$ shows that when heat is produced in an electric conductor, it is not proportional simply to the number of amperes passing, but to the square of the same. If, for instance, 2 amperes is flowing and transformed into heat, 4 amperes will not simply double the quantity of heat developed, but will increase it 4 times. Why this increase should be proportional to the *square* of the current-strength may not seem quite clear, and a practical example may help to make the matter better understood. When chemical energy is transformed into electrical energy, as, for instance, in a voltaic cell, the amount of material consumed per hour is proportional to the strength of the current. Suppose six Daniell cells are connected in series and are sending a current of 1 ampere through an external resistance. As the consumption of zinc per cell amounts to .043 ounce per ampere for each hour, the total amount of zinc consumed amounts to 6 × .043 = .258 ounce. If it is desirable to increase the current-strength to 2 amperes, while the resistance remains constant, then the E. M. F. must be doubled and therefore the number of cells increased to 12. As now each cell is transmitting a current of 2 amperes, twice the amount of zinc must be consumed, or .086 ounce per cell, and the number of cells now being 12, the total amount of zinc consumed is 12 × .086 = 1.032 ounces. This is 4 times .258 ounce, the original amount. We see then that to double the current-strength, 4 times as much chemical or electrical energy had to be developed, the electrical energy being proportional to the amount of material chemically transformed.

10. Conclusions.—From these considerations we come to the conclusion that the greater the number of watts transformed into heat the more rapidly the temperature must rise. Contrarily, the higher the specific heat of a conductor, or its capacity for heat, the more slowly will this rise take place, and, finally, the greater the mass or weight of the conductor the more time will be required to effect a rise in temperature.

CONDUCTION, CONVECTION, AND RADIATION

11. The increase in temperature of a conductor does not, as a rule, keep step with the number of watts spent in heating it, because heat, like electricity, is subject to losses from various causes. These losses may take place in three different forms, through conduction, convection, and radiation.

In *conduction*, the heat is transmitted from particle to particle in the body itself. In a heated electric conductor the heat would leak from the interior to the surface.

The transmission of heat by *convection* takes place in liquids and gases only, as it requires a certain mobility of the molecules of the substance. If a beaker of water is placed over a Bunsen burner, the bottom will become heated and the particles of water situated immediately above the same will be heated by conduction. When heated they become lighter and rise to the surface, thereby giving room to other particles. In this manner a constant stream of water will carry off the heat supplied by the bottom of the vessel.

When *radiation* goes on there is no direct contact between the source of the heat and the recipient of the same. The ether is in this case the transmitting medium and is able to transfer the heat from one place to another without itself being heated. For instance, the sun radiates its heat through space and in this manner supplies the earth with its necessary heat, but without heating the intervening medium.

12. Limit to Increase of Temperature.—A heated conductor may give up its heat by either one or all of these forms. If exposed to the air, the latter will become heated and, in passing away, set up a current that will constantly carry off heat from the conductor. The amount of surface a conductor exposes to the air will therefore be of importance in determining the rise in temperature. Thin wires heat more rapidly than thick wires of the same material, partly because they have less surface to dispose of the heat and partly because of the higher resistance. Suppose, for instance, that two wires, one $\frac{1}{32}$ and the other $\frac{1}{64}$ inch in diameter, have to carry the same current. The thinner wire will have a cross-sectional area $\frac{1}{4}$ that of the thicker; therefore, it has 4 times greater resistance and 4 times more heat units developed in it. But, as these heat units act on a mass 4 times smaller than that of the larger wire, there will be an increase in temperature 16 times greater in the smaller wire. Then again, it must be remembered that the smaller wire has a surface only one-half that of the larger wire, and consequently it will have more difficulty in getting rid of the surplus heat. As the thin wire grows hotter it will also increase in resistance, and its temperature will continue to rise until it has reached a point where there is a balance between the heat received and that given off by conduction and radiation.

13. Effect of Length.—If the resistance of a long conductor is the same as that of a short conductor with the same diameter, the number of heat units developed in both should be the same. But the increase in temperature of the long conductor may be hardly noticeable, partly because the heat has to be distributed over a larger mass and also because the longer wire has a greater radiating surface.

14. Effect of Heat on Resistance.—As already stated, the resistance of a metallic conductor increases with the temperature. The amount of this increase is about .38 per cent. per degree centigrade for pure metals. For instance, if a copper conductor has a resistance of 220 ohms and its temperature is raised 100° C., its resistance will increase to about 304 ohms. In general, it may be said that conductors *increase* and insulators *decrease* in resistance, when heated.

Certain metallic alloys used for high-resistance coils suffer a very small increase in resistance when heated, and some of them, notably manganin, actually decrease in resistance. Carbon and india-rubber decrease in resistance when warm, the latter very much so, even with a small increase in temperature. The increase in conductivity of carbon amounts to about .03 per cent. per degree centigrade. For instance, if the carbon filament of an incandescent lamp has 220 ohm's resistance, it will be reduced to 213 ohms at an increase in temperature of 100° C., and to 135 ohms at an increase of 1,280° C., which is the usual difference in temperature between hot and cold.

Liquids decrease in resistance by an increase in temperature. Water, when absolutely pure, does not conduct, but when mixed with gases or saline bodies, it is able to act as a conductor and its resistance will then depend on the resistance and quantity of these foreign substances. If 8 per cent. of sulfuric acid is added to the water, the resistance will decrease .65 per cent. per degree centigrade, so that a column of water with 1,000° ohm's resistance will, when the temperature is increased 100° C., have its resistance reduced to 350 ohms.

15. Different Temperatures in One Conductor. If part of a heated conductor, such as a cautery, be either cooled or heated, it will influence the total resistance of the circuit and increase or decrease the current-strength. Suppose, for instance, that a glowing cautery is brought in contact with living tissue. Part of it will then be cooled off, its resistance will be lowered, and the amperage will be increased. Consequently, the parts unaffected by the tissue will grow hotter. On the contrary, if the same part of a conductor has heat imparted to it, its resistance is increased, the current is reduced in strength, and the adjoining parts grow cooler. In the first instance, the outlying parts of the cautery may grow so hot as to fuse, therefore the importance of providing means, such as a rheostat, for regulating the current-strength through an active cautery.

16. Importance of Low Resistance in a Cautery Circuit.—As the cautery itself is of a very low resistance, it follows, as a consequence, that if a large amount of heat shall be developed in it, a current of high amperage is required. Under these circumstances a heavy current will naturally have to pass through the whole circuit, inclusive of the battery itself, and, if no heat shall be developed anywhere but in the cautery, it follows that the other parts of the circuit must have a resistance much lower than that of the cautery. If this is not the case, heat will also be developed in places where it is not desired, and where it would either be inconvenient to the patient or to the operator, besides being a useless waste of power.

For instance, if the cautery holders or the conductors leading to the latter are too small in diameter, then they are liable to get heated and in this manner will not alone waste heat, but will also, by their increase in resistance, reduce the current-strength and prevent the cautery from receiving its full quota of the total energy at disposal. A few examples will show the importance of this point.

A battery *B*, Fig. 1, producing an electromotive force of 4 volts and with an internal resistance of .02 ohm, is to supply the current to a cautery *C* of .035 ohm's resistance, and it is desirable to find the effect that the resistance of the conductors *W* between the cautery and battery will have on the current-strength of the latter. It is supposed that 20 amperes are required to heat the cautery and that two conducting-cords, of a joint resistance of .006 ohm, connect the battery and cautery. The total resistance of the circuit is, then, $.02 + .006 + .035 = .061$ ohm. If no rheostat is in the circuit, the current-strength $C = \frac{E}{R} = \frac{4}{.061} = 65.6$ amperes. To reduce this current to 20 amperes, a rheostat is installed and a resistance of .139 ohm is inserted so as to make the total resistance .2 ohm. By means of the rheostat this supplementary resistance may be increased or diminished as the circumstances may require. This extra resistance of .139 ohm corresponds to a loss in voltage of 2.78 volts, which is changed into heat in the rheostat.

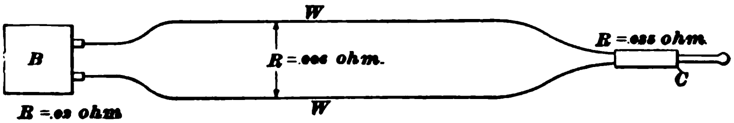

FIG. 1

If these conducting-cords of .006 ohm's resistance are replaced by some of .12 ohm's total resistance, the resistance of the whole circuit will be $.02 + .12 + .035 = .175$ ohm, and the maximum current-strength is $C = \frac{4}{.175} = 22.9$ amperes. There is now a surplus resistance of $.2 - .175 = .025$ ohm, only, which represents a loss in voltage of 20 amperes × .025 ohm $= .5$ volt, which is a very small margin when it is considered that the heating of the circuit will increase the resistance materially and that a bad connection somewhere may consume this surplus. If the whole resistance of the rheostat were switched out, it would in this case have little or no compensating effect on the increased resistance of the circuit. The influence of the two conductors will be more clearly shown in the following table:

TABLE II

	Conductor of .006 Ohm's Resistance	Conductor of .12 Ohm's Resistance
Resistance of cautery	.035 ohm	.035 ohm
Resistance of circuit exclusive of rheostat	.061 ohm	.175 ohm
Resistance of circuit inclusive of rheostat	.200 ohm	.200 ohm
Surplus resistance in rheostat . .	.139 ohm	.025 ohm
Surplus voltage consumed in rheostat	2.780 volts	.500 volt
Current in the circuit with rheostat	20.000 amperes	20.000 amperes
Percentage of total pressure lost in conducting-wires	3.0	60.0
Percentage lost in cautery . . .	17.5	17.5
Percentage lost in battery . . .	10.0	10.0
Percentage lost in rheostat . . .	69.5	12.5

17. Cautery Battery of Low Resistance.—When it is so important to reduce the resistance of the conductors to a minimum, it can easily be seen that the resistance of the battery must also be as small as possible. Suppose, for instance, that the attempt should be made to run the above cautery by means of two Leclanché cells, each with an E. M. F. of 1.7 volts and internal resistance of .8 ohm. Arranging the cells in series, their joint pressure will be 3.4 volts and their resistance 1.6 ohms; adding to this the resistance of the conducting-cords and the cautery, the total resistance will be $1.6 + .006 + .035 = 1.641$ ohms.

Therefore, $C = \frac{3.4}{1.641} = 2.072$ amperes, instead of the 20 amperes required. As it was shown in Art. **138,** *Direct Currents*, that an increase in the number of cells in series with a small external resistance does not increase the current-strength, it is useless to add any more cells. The only possible improvement would be to connect the cells in parallel. Then the total pressure would be that of one cell, or 1.7 volts, and their joint resistance $\frac{.8}{2} = .4$ ohm. The total current would then be $\frac{1.7}{.4 + .006 + .035} = \frac{1.7}{.441} = 3.8$ amperes, which is still entirely inadequate. It would take ten of these cells in parallel before a current of sufficient strength could be obtained. Even so, a battery of these cells would be unsuited for the purpose, because cells of this class are unable to furnish a heavy current except for very short intervals, polarization taking place very rapidly, reducing the current-strength.

If we select some cells with a higher E. M. F. and lower resistance, such as bichromate cells or cells with very low internal resistance as, for instance, the Edison-Lalande cell, better results will be obtained. Selecting two cells of the latter class with an E. M. F. of .7 and an internal resistance of .03 ohm, we would, by arranging them in series, receive a current of $C = \frac{2 \times .7}{2 \times .03 + .006 + .035} = \frac{1.4}{.101} = 13.8$ amperes. This is, also, entirely insufficient, but we notice at once the advantage over the other two cells in series. To obtain something like 20 amperes from this class of cells, four are required, arranged two in series and two in parallel.

When the minimum internal resistance is desired, we have to resort to the storage-battery, where the resistance may be about .005 ohm and where the discharge, theoretically, may be at the rate of $\frac{2.0}{.005} = 400$ amperes. This high rate of discharge is, of course, not permissible, because it would ruin the plates; but even so, the possible rate of discharge is so high that an ordinary voltaic battery cannot compete with it.

The method pursued above for ascertaining the current-strength is to use formula (*a*), Art. **128,** *Direct Currents.* This is usually sufficient, but those who wish to go a little further may use formulas (*d*) and (*e*), Art. **135,** and formula (*g*), Art. **136.**

CURRENT-SUPPLY FOR THE CAUTERY

18. The Bichromate Cell.—Regarding the most convenient method for supplying the current to the cautery, it is needless to say that the ordinary lighting circuit takes first place, next to this comes the accumulator, and last the primary cells. Among the latter, the *bichromate cell*, Art. **35,** *Direct Currents*, has occupied a prominent place, because it has a high E. M. F., a comparatively low resistance, and is able to deliver a heavy current for some time without polarization. There are many forms in the market, mostly consisting of a combination of a number of single elements. Fig. 2 shows a form provided with a tight cover, which allows the liquid to splash about inside without spilling. In a bichromate cell the zinc should always be removed when not in use, in order to prevent local action. This is here accomplished by raising the cover and turning it around so as to place the plates in the empty side of the case. The other half is divided into cell-compartments, each containing an electrolyte. Fig. 3 shows another form where the electrolyte is kept in a bottle when not in use. Numerous other forms are produced, so as to make the

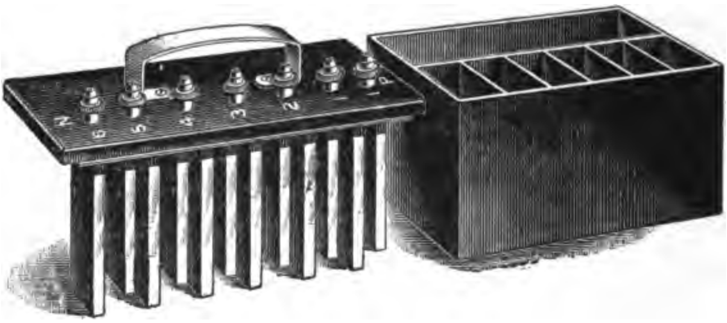

FIG. 2

cells more portable. These cells all need a certain amount of care, if they are to be relied on when wanted. If not systematically inspected, they are liable to fail when any heavy service is required of them.

In Arts. **92** and **94**, *Direct Currents*, are given some particulars relating to the care of these cells. It should here be added that in a bichromate cell there is no liberation of gas and, therefore, no motion takes place in the electrolyte whereby the exhausted parts of the solution may be made to move away and make room for the fresh parts. The strengthening of the old solution goes on mostly by means of diffusion, unless the plates are lifted at intervals so as to set the liquid in motion. It is therefore of importance to have the electrolyte in a concentrated form, and this cannot be done with bichromate of potassium, even if dissolved in hot water. But, if bichromate of sodium is used in its place, it can not alone be dissolved in cold water, but almost in any quantity. A battery will then need less frequent renewals of the electrolyte, and will be able to furnish a heavier current for a longer time without being subject to a decrease by the diminished action of the electrolyte. Carhart recommends the following solution: Dissolve 7 ounces of sodium bichromate in 1 quart of water, and to this should be added 5 fluid ounces of strong sulfuric acid. The solution is ready for use as soon as it cools. When the battery begins

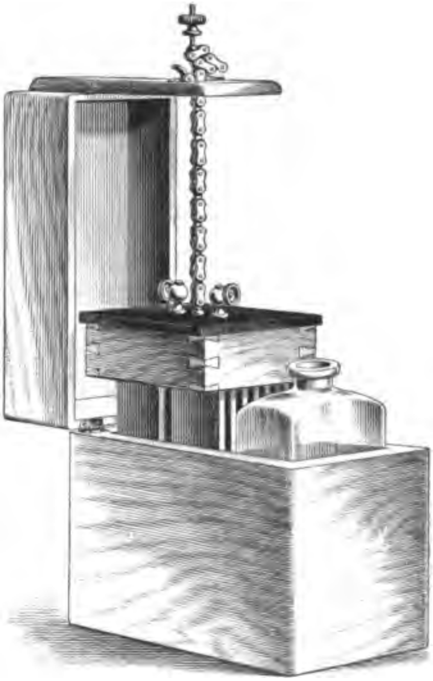

FIG. 3

to show signs of exhaustion, add from 1 to 1.5 ounces of acid per quart of fluid.

When it is intended to use a bichromate battery for cautery work, it is advisable not to have the zincs in contact with the electrolyte longer than is absolutely necessary, and after use the zincs should be washed out in water. If the cautery current has been one of great strength and taxed the battery to its limit, it is better to throw the liquid away, unless it still has sufficient strength to run the battery for other purposes where a current of small strength is required.

19. The Edison-Lalande Cell.—When a battery is desired for office-work alone and not for transportation, then the *Edison-Lalande* battery is very serviceable. It will keep in working order for a long time without any attention, except an occasional examination every 2 or 3 months to ascertain the height of the liquid, as the latter will evaporate even when covered with oil. The type "W" cell has a resistance of about .02 ohm, and one cell can, for a short time, deliver a current of 33 amperes, if necessary; but usually they are put up in combinations of three cells, when they can also be used continuously for motors and similar work, and are able to supply a current of over 20 amperes. The lack of success that some operators have had with these cells is mainly caused by not following the rules given by the manufacturers. Another cell, based on the principles of the Edison-Lalande cell, is the *Gordon* cell. It is somewhat different in construction, but otherwise there is little difference between them.

20. Dry Cells.—Some *dry cells*, such as the "New Standard," "Hydra" battery, and others, have also been used for cautery work and to a great extent for lamps. They require no attention and are very suitable for transportation. Their resistance is not as low as that of the fluid cells and they cannot be renewed, but many operators prefer these disadvantages to those of having to keep the cells in working order and to handle acids, etc.

21. Care of Cells.—Regarding the care of cells, then, the essentials have already been given in Art. **92**, *Direct Currents*.

It may be added that sometimes a battery, which otherwise seems to be in perfect order, fails to give the usual current-strength. In this case the fault may lie with one single cell, which either has a wasted zinc or some loose contact. It is well, then, to give each separate cell a close examination and, preferably, to test them by means of a voltmeter.

22. Storage-Battery.—Whenever a storage-cell can be conveniently charged it is preferable to a primary cell, provided it is in frequent use. If this is not the case, then it is better to have one of the primary batteries mentioned, because a storage-battery, if not submitted to a certain amount of work, will deteriorate in a short time. The price paid for it had then better be devoted to a primary battery. Complete information about the storage-battery has already been given in Art. **57**, *Direct Currents*.

The main point about a storage-battery is the rate of its discharge, taking care that it does not go beyond that indicated by the manufacturer. If so, buckling and sulfating are liable to occur, and it will never be able to run at its full capacity again. The charging of the battery should also be at the stated rate. As a transportable battery, it has great advantages by being able to deliver a heavy current without too much bulk. If regularly used, then a systematic charging process should be gone through with at regular intervals, so that the battery is always charged and ready for service. If the lighting circuit is not available, a primary battery must be resorted to, and then every available moment should be used for charging purposes. Otherwise a very large primary battery is required in order to finish the charging process within a reasonable time. When ordering a storage-battery, the purpose for which it is to be used should be stated, and also the means for charging it. The manner in which a primary battery is used for charging accumulators is fully described in *The Physics of Roentgen Rays*.

If the 110-volt incandescent-light circuit is utilized for charging purposes, then the arrangement shown in Fig. 4 may be made. The current comes in through the conductor *a* from the main circuit and passes through a number of incandescent lamps, depending on the desired current-strength. In this instance ten lamps of 16 candlepower are installed, each permitting $\frac{1}{2}$ ampere to pass, therefore a total of 5 amperes. From here the current passes through a fuse and switch to the adapter, ammeter *A*, and accumulators. In parallel with the battery is inserted the voltmeter *V*, enabling the operator to ascertain the progressive state of the charging at the same time as the

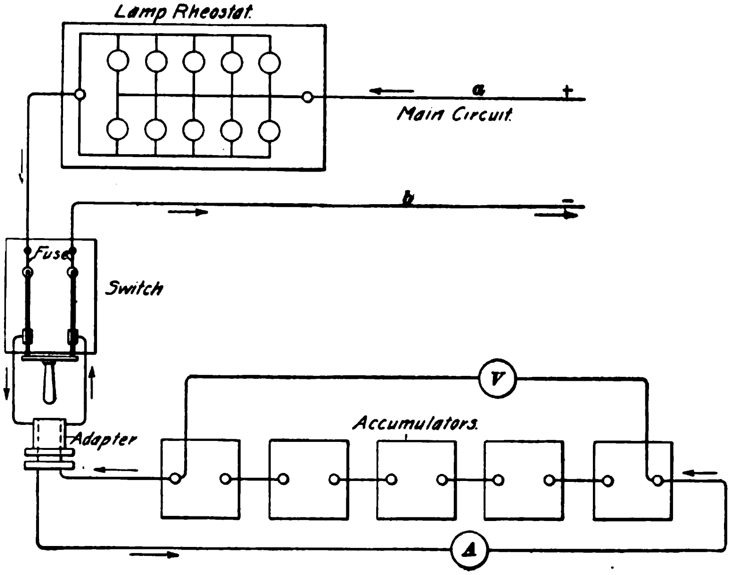

FIG. 4

ammeter *A* indicates the rate at which it takes place. From the battery the current returns again through the adapter, switch, fuse, and main conductor *b*.

When a primary battery is used for charging it is important to have a rheostat in the circuit whereby resistance may be thrown out of the circuit when the charging progresses. This is to counteract the counter E. M. F. of the accumulator, which constantly increases while the charging is going on, tending to decrease the current-strength. The latter should be kept as nearly constant as possible. If too great, gassing and buckling may be caused. The method for calculating the time of charging the storage-battery has been given in Art. **30,** *The Physics of Roentgen Rays.*

23. Lighting Circuit.—The minimum of attention is required on the part of the operator when the incandescent-lighting circuit is utilized. All that is required under this arrangement is simply to close a switch and the current is flowing. Ordinarily there are two kinds of currents available, the *direct* and the *alternating.* The most universally useful of the two is the direct current, because the alternating cannot be used in cataphoresis, electrolytic, and galvanic treatments. For cautery and lamps it is immaterial which current is used.

It would seem natural to suppose that a 110-volt lighting current could be used directly for cautery purposes, and that by inserting a resistance-coil or a number of incandescent lamps of suitable resistance in parallel, any current-strength could be obtained. But this method has certain drawbacks that make it objectionable. A cautery has a very low resistance, and, to send a current of the required strength through it, demands a comparatively low pressure. For instance, let the united resistance of the cautery and conductors be .1 ohm; then, with a pressure of 110 volts the amperage would be $C = \frac{E}{R} = \frac{110}{.1} =$ 1,100 amperes. As the required amperage rarely goes beyond 25, and usually is much below this, it is clear that a large resistance must be inserted in the circuit to bring the pressure within reasonable limits.

Suppose that we desire a current of 5 amperes for a cautery of .035 ohm's resistance. It is then necessary to insert a resistance in the circuit, in series with the cautery, sufficiently large to make the joint resistance of the cautery and conductors equal to 22 ohms, as found by Ohm's law, viz.: $R = \frac{E}{C} = \frac{110}{5} = 22.$ Let the united resistance of the cautery and the conductors be .1 ohm, then the resistance of the rheostat would be $22 - .1 =$ 21.9 ohms. The reduction of pressure that takes place in this resistance is $E = C \times R = 5 \times 21.9 = 109.5$ volts, and the number of watts lost is $W = E \times C = 109.5 \times 5 = 547.5$ watts, a useless waste amounting to 99.4 per cent. of the total 550 watts at disposal. It is therefore necessary to find other means whereby the available pressure may be reduced to one suitable for the operation of the cautery. This is done by transforming a current with a relatively high voltage to one with a lower voltage, but with an increased amperage. If the current is *alternating*, this can be done by means of a transformer in the manner described in Arts. **58** to **62**, *Essential Apparatus.* Various designs of these transformers are in the market, some more efficient than others. That one shown in Fig. 5 is not of a very high efficiency and requires a heavy primary current to produce an E. M. F. high enough for sending a heavy current through the movable secondary coils, one of which is used for the cautery and the other for light. This is because the lines of magnetic force have to complete their outside paths for a long distance through air, making the magnetic circuit one of high resistance, and therefore requiring a correspondingly heavier current to produce the same results as an apparatus in which the lines of force may travel almost entirely through iron. A transformer of the latter class is shown in Fig. 6. Here the primary and secondary coils are entirely enclosed in laminated iron. The strength of the cautery current is regulated by means of the hand-wheel on top that moves a small lever from one button to another. Each button means an addition of one-half

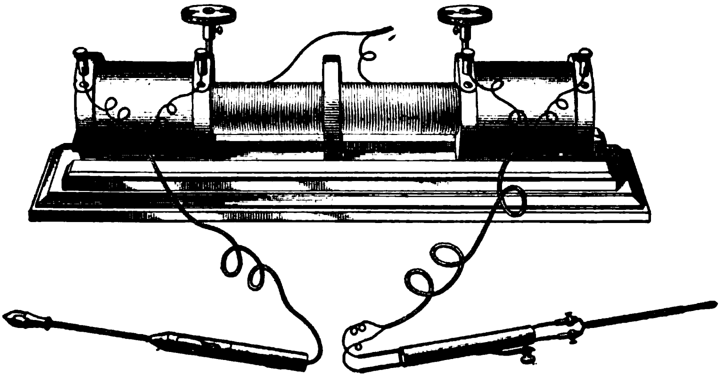

FIG. 5

volt, the maximum current having a voltage of 6 volts. The transformer can be attached to any ordinary lamp-socket of a 55- or 110-volt circuit, the three binding-posts to the left being for that purpose. On the right are binding-posts for the cautery connections.

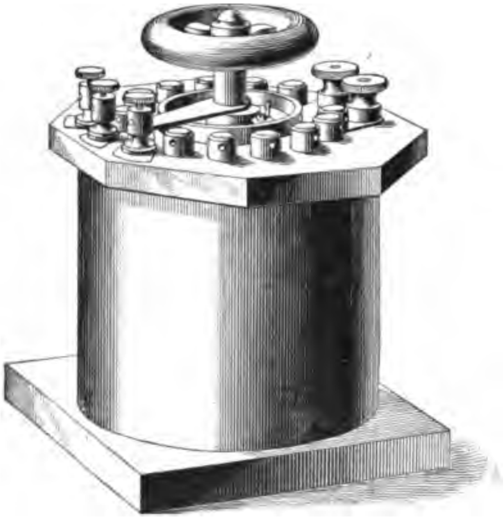

FIG. 6

When the *direct* current has to be transformed, the procedure is not quite so simple, because a motor-generator, or rotary-converter, is required in addition to the transformer. A motor-generator consists, in reality, of an electric motor that is operated by a direct current. On the motor shaft is also a supplementary armature that revolves in the magnetic field of the motor and has an alternating E. M. F. produced in it, suitable for the operation of the transformer shown in Fig. 6. In Fig. 7 is a diagram showing the connections of the motor-generator with the lighting circuit, transformer, and cautery. *A* is the current-tap, inserted in any lamp-socket, from which the conductors *a*, *a* transmit a 110-volt current to the motor brushes of the motor-generator *B*, setting its armature in rotation. An alternating current of 70 volts is then taken from the collector-rings on the left side of *B* and sent through the conductors *b*, *b* to the transformer *C*, where it is changed into a 6-volt alternating current, with a corresponding increase in amperage. This current is now led through the conductors *c*, *c* to the cautery *D*.

When buying apparatus of this class it is always advisable to specify the voltage of the circuit from which it is intended to derive the operating current. The construction of the apparatus varies with the variation in voltage. The motor can also be used for any other purpose where driving power is required, such as static machines, centrifuges, etc.

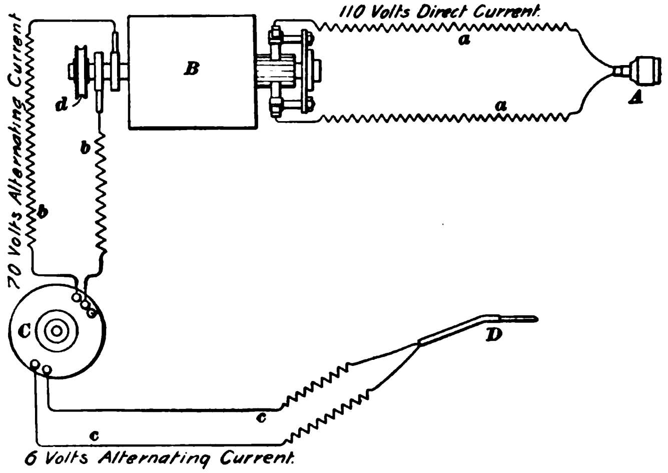

FIG. 7

CAUTERIES

24. In Art. **16** was explained the theory of the cautery, and it remains here to treat of its practical construction and of the variations in form that the various purposes for which it is used demand of it. Platinum is the metal that is almost exclusively used for cauteries, though at times thin steel and iron wires have been utilized for the same purpose. Platinum has the advantage over other metals that it is of a high specific resistance and low specific heat, and of a high fusing temperature, therefore not easily melted when exposed to a high temperature.

25. Construction of the Cautery.—The resistance of a cautery seldom exceeds .1 ohm, while the volts vary between 2 and 6 and the amperes between 1 and 50. A broad knife may take as much as 25 to 30 amperes at a pressure of 1 volt. If the cautery is a long, thin wire, considerable more E. M. F. may be needed, but the total energy transformed into heat may be small, because the resistance is higher.

Some cauteries are made rather heavy; this should be avoided, as thereby the resistance is lowered, and, consequently, a heavier current is needed to reach the same temperature. There is then more danger of the rest of the circuit also getting heated, resulting in an increase of resistance and waste of power. The copper conductors to which the platinum loop is attached should be of ample size and well insulated. The difference in pressure between these two copper wires is not great, but it is, nevertheless, important that no current passes from one to the other before it flows through the platinum loop. Therefore, the insulation should be good and should be of such material that it can be readily sterilized. Usually silk and asbestos are used for this purpose, being covered with varnish to make it waterproof. It is needless to say that absolute cleanliness should be the rule, so as to prevent organic matter from being lodged between the conductors.

26. Resistance of the Cautery Circuit.—In Art. **16** attention was called to the importance of having the whole cautery circuit, external to the cautery itself, of a minimum resistance. This emphasizes the importance of having all the joints and connections perfect, electrically considered. Metallic oxids are poor conductors, and, if found on any of the electrodes and joints, must at once be removed. For instance, the ends of the cautery that are inserted in the handle should always be examined, and, if oxidized, should be rubbed off with some fine emery-paper; likewise, the ends of the conducting-cords that are inserted in the other end of the handle. The connection between the several elements of the battery should also be frequently inspected, as corrosion is, in particular, liable to occur in the presence of acids.

It has already been remarked in Art. **15** that the cautery, after coming in contact with moist tissue, is considerably cooled. As a consequence, some allowance should be made so that the cautery may receive a somewhat heavier current when in active operation than that which seems sufficient to make it glow while surrounded by air.

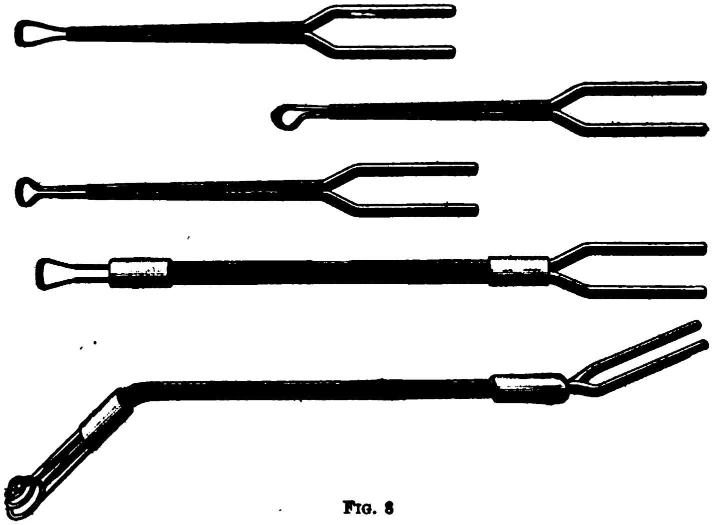

FIG. 8

27. Variety of Cauteries.—Fig. 8 shows a few forms of cauteries most in use. Where a larger incandescent surface is required, a loop or spiral of platinum, supported in grooves on a porcelain mount, is made as shown in Fig. 9, the porcelain being heated to redness with the platinum.

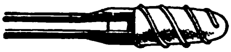

FIG. 9

28. Cautery Handle.—Fig. 10 shows the cautery handle into which any of the cauteries may be inserted and, likewise, part of the conducting-cords by which the current is sent from the transformer to the cautery.

The aim should be to have the cautery handle light and well balanced, otherwise the delicacy of the operations, for which the cauteries, as a rule, are used, are interfered with.

The metal handle should be well insulated from the end sockets into which the conductors and cautery are inserted.

Some handles are provided with an interrupter for starting and stopping the current through the cautery. This has some objections, mainly this, that the hand of the operator has to perform an additional motion, which of necessity must interfere with the stability of the cautery. A better method would be to use a foot-switch or to have an assistant do the starting or stopping of the current.

29. Cautery Snare.—For the removal of a greater quantity of tissue the electrocautery snare is used. The ordinary handle, as shown in Fig. 10, may also be used for operating this snare, and is then provided with a little wheel by means of which the platinum snare may be drawn up. This arrangement does not seem to be very satisfactory, as it is difficult to produce an even pull and to prevent a certain jerkiness. In many operations where the cautery snare is used, it is required to submit the latter to a constant pull, and, in some cases, of considerable strength. The handle, Fig. 11, is constructed with the aim of fulfilling these requirements. Here the fingers are inserted in the three rings, and by bending the fingers towards the thumb, the snare is drawn in with an even motion and with a speed that can be easily regulated. When using the snare it should be remembered that, while it is being drawn into the handle, its resistance is constantly decreasing. The resistance of the circuit should, therefore, be correspondingly increased, otherwise there is danger of the platinum wire being overheated and

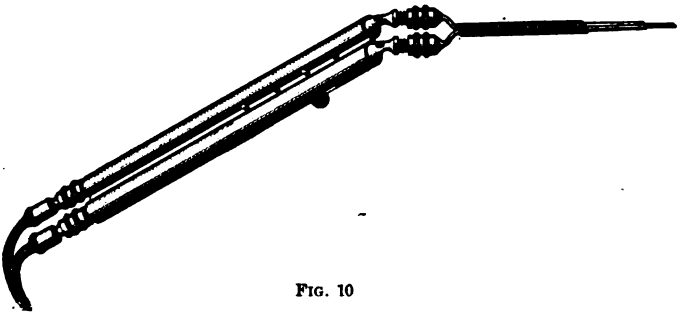

FIG. 10

melted. The snare handle here illustrated has a resistance that is automatically increased while the snare is being shortened.

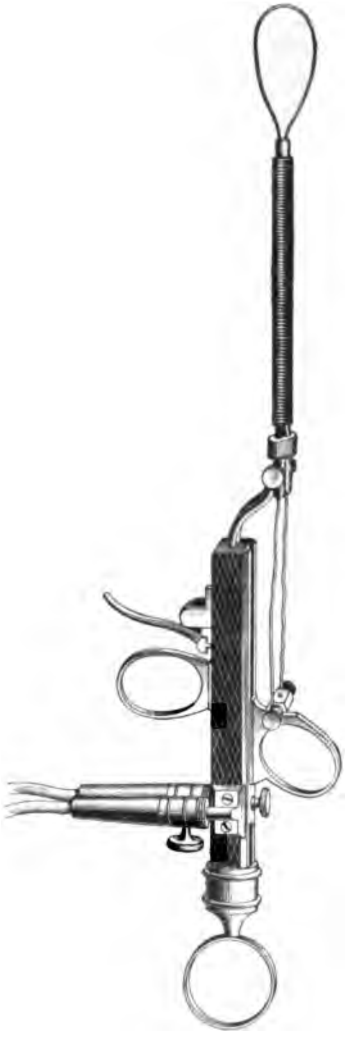

FIG. 11

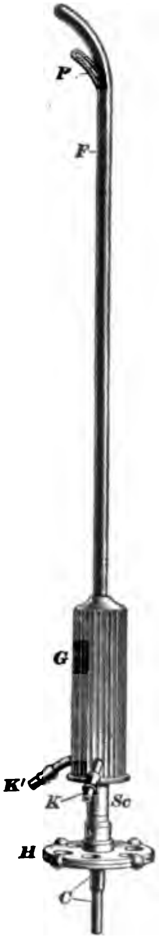

FIG. 12

30. Bottini's Incisor.—A special form of cautery is *Bottini's* incisor, Fig. 12, used for incision of the prostrate gland. The female shaft *F* contains the cautery knife *P*, which may be moved in or out by turning the wheel *H*. To keep the shaft cool while the cautery is heated, a stream of cool water is circulated through the handle *G* and shaft *F* by letting the water pass in through the pipe *K* and out through the pipe *K'*. *C* is a plug that, inserted in a sleeve, connects it with the copper conductors. The advantage of the cautery is perhaps here shown at its best. While the shaft is being inserted the blade *P* is entirely covered and the whole is cold. The current is sent through the cautery after the desired position has been found and the operation performed in about a minute, after which the cautery is again sheathed, the current cut off, and the whole withdrawn in a cool condition.

ELECTRIC LIGHTING

INCANDESCENT LAMPS

31. The Filament.—The active part of an incandescent lamp is a thin filament of carbon mounted on platinum wires that are sealed in the neck of an evacuated glass globe. The thickness of the filament determines the resistance of the lamp and, thus, the voltage necessary to send a current of a given strength through it. In some small lamps a platinum wire is used in place of the carbon filament. More care is then required in using the lamps, as a current of too great intensity is liable to fuse the platinum.

32. Unit Candlepower.—The light that an incandescent lamp emits is measured in candlepowers, some lamps having as little as ½ candlepower and others as much as 1,000. The standard candlepower is the light produced by a candle burning 2 grains of spermaceti wax per minute.

33. Variation in Candlepower.—The lamps ordinarily used for offices and operating-rooms are 16 candlepower, which is abbreviated to 16 c. p. The number of candlepowers that a lamp is able to give out depends on the amount of electric power that the lamp transforms into light and heat. We have already seen that electric power is measured in watts, and the number of watts that a lamp utilizes is found by multiplying together the pressure and strength of the current through the same.

For instance, the resistance of a lamp may be 220 ohms and the voltage 110. The current-strength is then $C = \frac{E}{R} = \frac{110}{220}$ $= .5$ ampere. The product of voltage and amperage is $110 \times .5 = 55$ watts. The number of watts required to produce 1 candlepower varies between 3 and 4.5; small lamps used for diagnostic purposes may require as much as 8 watts per candlepower. Counting, in this instance, 4 watts per candlepower, we find the candlepower of this lamp to be $\frac{55}{4} = 13.75$. This is when the lamp is new, but its candlepower is not constant. A gradual decrease of the latter goes on, caused partly by the disintegration of the carbon filament, whereby its diameter is reduced and its resistance correspondingly increased, and partly, also, by the deposition of the removed carbon particles on the inside of the lamp-globe. The latter is thereby made more or less opaque and the efficiency of the lamp reduced.

The lamps used for diagnostic purposes vary in illuminative power from 1 to 16 candlepower. The pressure required for their operation is usually between 4 and 110 volts. It is clear that the same candlepower may be produced by lamps of varying voltage and amperage as long as the watts consumed are the same. For instance, a lamp of 10 volts and .75 ampere would, theoretically, have the same candlepower as one with 6.5 volts and 1.25 amperes. In both cases the number of watts utilized is 7.5, but in general it is found that lamps using more than .9 ampere are more efficient than those requiring a smaller current-strength.

The table on the following page shows, approximately, the variations in voltage and amperage for the same candlepower.

34. Selection of Lamps.—When procuring ordinary diagnostic lamps, considerations should be had of the available voltage and a lamp selected that is most suitable for it. To be on the safe side it is well, for small lamps, to count about 8 watts per candlepower. The following example will show how such calculations are to be carried out. To find the total number of watts required for a lamp of a given candlepower, multiply the candlepower of the lamp by the number of watts per candlepower, or, total watts $W =$ total candlepower $\times$ watts per candlepower. For example, an 8-candlepower incandescent lamp requires 3.5 watts per candlepower; how many watts are needed for its operation? $W = 8 \times 3.5 = 28$ watts. A current of 10 volts is available; how many amperes will it require? According to Art. **20**, *Direct Currents*, $W = E \times C$, therefore,

$$C = \frac{W}{E} = \frac{28}{10} = 2.8 \text{ amperes.}$$

TABLE III

1	c. p.	from	3 volts and	.8 ampere	to	8 volts and	.3 ampere
2.5	c. p.	from	5 volts and	1.4 amperes	to	25 volts and	.45 ampere
5	c. p.	from	5 volts and	3.0 amperes	to	65 volts and	.35 ampere
8	c. p.	from	10 volts and	2.8 amperes	to	120 volts and	.3 ampere
16	c. p.	from	15 volts and	3.7 amperes	to	160 volts and	.4 ampere
25	c. p.	from	40 volts and	2.2 amperes	to	120 volts and	.7 ampere
32	c. p.	from	50 volts and	2.3 amperes	to	120 volts and	.9 ampere
50	c. p.	from	50 volts and	3.5 amperes	to	120 volts and	1.4 amperes
100	c. p.	from	50 volts and	7.0 amperes	to	120 volts and	2.9 amperes

35. Selection of a Battery.—The same battery that will serve to operate a cautery will not, as a rule, be able to run an incandescent lamp unless the battery is rearranged to fill the new requirements. The reason for this is that in a cautery we have to do with a very low resistance, perhaps as small as .025 ohm, while in an incandescent lamp the resistance may be as high as 400 ohms, depending on the candlepower of the lamp and the pressure of the current. In the cautery it is a question of developing a maximum of heat, and in the incandescent lamp a minimum heat with a maximum of light.

As the lamp has a resistance so much higher than that of the cautery, it is necessary to have a battery with a high E. M. F.

and a relatively small current-strength. The resistance of the battery in this instance plays a more subordinate rôle, because the amperage is small, and, therefore, the product of current into resistance, that is, the loss of potential, cannot reach the height it would in a cautery circuit. It is thus seen, that while in a cautery-battery the aim is to produce a maximum current-strength by putting the cells in *parallel*, in an incandescent lamp-battery the aim is to produce a higher voltage by placing the cells in *series*. Whether either of these combinations alone is sufficient to produce the desired voltage or amperage will depend to a great extent on the E. M. F. and the resistance of the individual cells, and on the current-strength demanded either by the cautery or the lamp.

Suppose, for instance, that an incandescent lamp with a resistance of 4.8 ohms requires a current of 1.25 amperes to bring it to proper incandescence. A battery of six Edison-Lalande cells, used for the cautery, is at hand, and it is desirable to ascertain if these are able to run the lamp. The E. M. F. of each cell is .7 volt and internal resistance .03 ohm. Arranging the cells in series we find the current-strength, according to formula (*b*), Art. **128,** *Direct Currents*, to be

$$C = \frac{s\,e}{s\,r + R} = \frac{6 \times .7}{6 \times .03 + 4.8} = \frac{4.2}{4.98} = .84 \text{ ampere.}$$

The result shows that this number of cells is entirely inadequate for lighting this particular lamp. This does not mean that a greater number of cells may not do so, or that another lamp requiring less pressure may not be run successfully.

On taking six bichromate cells, each of 1.9 volts E. M. F. and .5 ohm's resistance, we find, on arranging them in series, that they will give a current of $C = \frac{6 \times 1.9}{6 \times .5 + 4.8} = 1.46$ amperes, a current of sufficient strength to light the lamp and to allow the insertion of a resistance for regulation.

The number of watts utilized in a lamp may, of course, be varied, either by increasing the E. M. F. or the amperage of the current, or by decreasing the resistance of the circuit, the latter method being accomplished by the use of a rheostat. It should be remembered, however, that increasing the candlepower beyond that at which a lamp is rated is very injurious and results in a quick deterioration of the same.

36. Using the Lighting Current.—The other means used for operating the diagnostic lamp are the same as those used for the cautery, with the modifications in E. M. F. and current-strength, which have already been mentioned. The transformer shown in Fig. 5 is made both for light and cautery, the coil on the left giving the current for the light and on the right for the cautery. In other cases the current is received directly from the lighting circuit, but may then have to be reduced to the required voltage by means of a rheostat, which is not a very economical method. Rotary transformers may also be used for this purpose, from which a current is received with the correct voltage. When the commercial current cannot be obtained, recourse must be had to a battery, either made up of voltaic cells or storage-cells. Voltaic cells in the form of dry cells have also been used successfully.

37. Portable Battery.—When using voltaic cells for office-work, the gravity, bichromate, and Edison-Lalande cells are all serviceable. For portable purposes the dry cells are the most desirable. The formulas given for combining cells for cautery purposes are also used when calculations have to be made to ascertain the best combination for operating a given lamp. As a lamp of, say, 8 candlepower is made for a voltage varying between 10 and 120 volts, it is well to procure a lamp of a voltage that will be run by a battery of minimum weight, when intended to be portable. If, for instance, the voltage is too high, then a large number of cells are required, which, in case of a storage-battery, would be inconvenient. It would here be better to have the voltage as low as possible in order to require a minimum number of cells. For portable purposes the dry cells are to be preferred. They are not quite as economical as the ordinary cells, but they are very clean, require no attention, and do not deteriorate when not in use. They may be bought in quantities ready for replacing worn-out cells. This matter of deterioration is quite an item with storage-batteries, and unless they are used very frequently they are rather expensive and troublesome to maintain in good working order.

38. Head-Light.—For diagnostic purposes the lamp is required to light only a limited area, and for this reason it is possible to concentrate the illumination in one direction. Consequently, the illuminative power of the lamp for a given area may be increased fourfold to fivefold, depending on the area and the means used for concentration. It is also of additional advantage to have the operator's eyes shielded from the lamp, in order to study the illuminated parts to the best advantage.

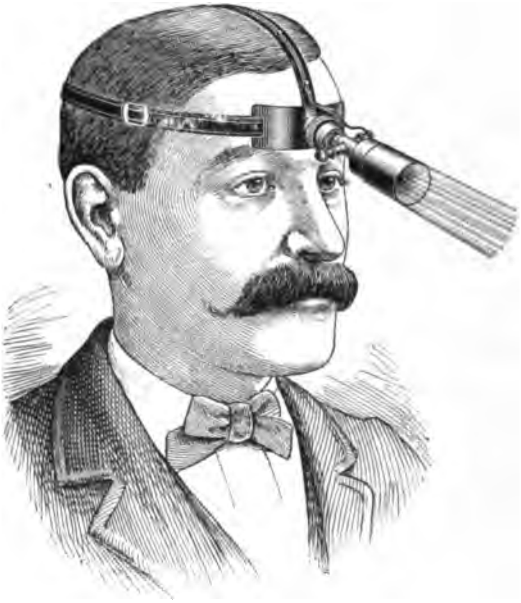

FIG. 13

Such an instrument is shown in Fig. 13, where the lamp with its reflector and condenser is fastened by means of a belt. The operator is then allowed the use of both hands and can also change the direction of the light to suit the requirements. When it is impossible in this manner to throw the light on the parts desired, as, for instance, in throat and nasal examinations, a hand-lamp may be used, as shown in Fig. 14.

39. Cystoscope.—When it is desirable to illuminate cavities and observe the surrounding walls, such as the stomach or bladder, it is necessary to send the light reflected from these walls through a long tube and to enlarge the image thus found by means of suitable lenses. This is done by means of the cystoscope illustrated in Fig. 15. *A* is the lamp situated at the extreme end of the tube *T*. *B* is a prism that receives the image and refracts it through the tube in a longitudinal direction and through a lense placed at *G*, where it is magnified. As the lamp generates some heat, several designs have water circulating through the tube for the purpose of cooling it. The filaments in these small lamps are quite delicate and they should be handled with care to avoid permanent injury.

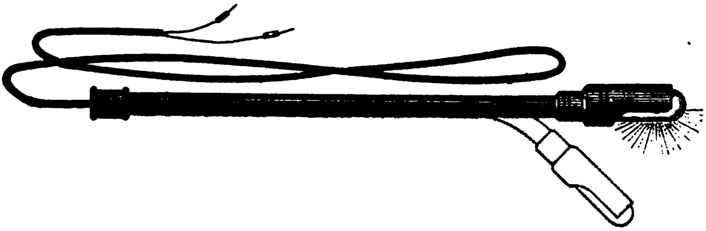

FIG. 14

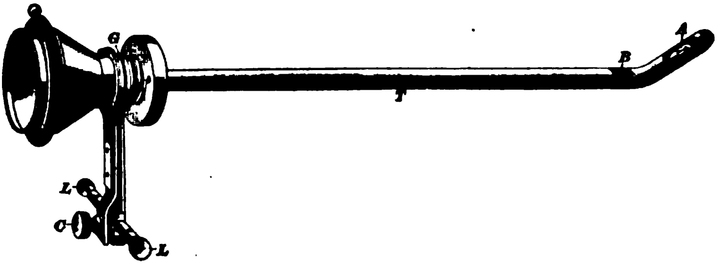

FIG. 15

40. Urethroscope.—Fig. 16 illustrates an improved form of urethroscope in which the lamp is held more securely than in most other forms, and where there is less danger of getting the application entangled with the lamp. The main tube is marked *a* and is provided with an opening at its extremity through which the obdurator *b* projects. The latter is grooved on its under side so as to allow space for the lamp. The tube, obdurator, and lamp are all introduced simultaneously into the urethra, as shown in Fig. 16 (*a*). The handle *h* is provided with studs *f*, to which are attached the conducting-cords from the battery. On the front and rear of the handle are push-buttons *e* for starting and stopping the current. Fig. 16 (*b*), (*c*), (*d*) shows the obdurator, the lamp with its carrier, and the tube *a* without the obdurator. By reason of the position of the lamp there is more direct illumination of the urethra, and the degree of heat imparted to the urethra by the lamp is reduced to a minimum.

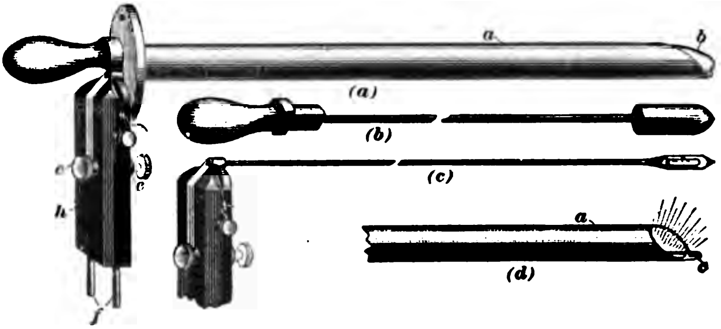

FIG. 16

A SERIES OF QUESTIONS

RELATING TO THE SUBJECTS
TREATED OF IN THIS VOLUME.

It will be noticed that the questions contained in the following pages are divided into sections corresponding to the sections of the text of the preceding pages, so that each section has a headline that is the same as the headline of the section to which the questions refer. No attempt should be made to answer any of the questions until the corresponding part of the text has been carefully studied.

THE PHYSICS OF ROENTGEN RAYS.

EXAMINATION QUESTIONS.

(1) What difference is there between the static machine and other sources of electric energy, as regards the production of Roentgen rays?

(2) Why cannot the current from batteries, dynamos, etc. be used directly for producing Roentgen rays?

(3) What factors determine the strength of an electric current?

(4) Can you name some other instances in nature where these properties play the same role?

(5) What is meant by the electromotive force of a current?

(6) To what does the amperage of a current refer?

(7) What other terms can you name that are equivalent to electromotive force?

(8) Does intensity refer to pressure or rate of flow?

(9) What unit is used to express the power of a current?

(10) What two factors must be known in order to determine the power of a current?

(11) A current with a pressure of 5 volts flows at the rate of 20 amperes. What is its power in watts?

(12) How much greater power has a current of 100 volts and 2 amperes?

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(13) Has the length, sectional area, and interior surface of a tube any effect on the final pressure and flow of water through said tube?

(14) Name the factors that influence an electric current in a similar manner.

(15) How does the temperature of a conductor affect its resistance?

(16) When is a terminal of a battery called positive?

(17) Of what sign is the cathode?

(18) What term is applied to a current that flows in one direction only?

(19) Why is a current called alternating?

(20) What does a source of electric energy really represent?

(21) What is meant by a voltaic cell?

(22) In what direction does the current flow through the negative pole of a voltaic cell?

(23) Is there any pressure in a voltaic cell if no current is flowing through it?

(24) What effect does an increase in resistance have on the current flowing through a circuit?

(25) What effect does the pressure have on the current strength, according to Ohm's law?

(26) How is the current strength found by means of Ohm's law?

(27) If the pressure produced by one cell is insufficient and two cells are required, how should they be connected and what is this combination termed?

(28) If the current strength derived from one cell is too weak and three cells are needed, how must they be connected, and what is the term applied to this combination?

(29) If six cells are to be arranged so as to give a current with a pressure of three cells and a volume corresponding to that of two cells, how should they be arranged, and what combination do they constitute?

(30) If a cell furnishes a current of 3 amperes for 40 hours, how many ampere-hours does it give?

(31) What does an accumulator really store?

(32) What terminal of a storage-battery, when undergoing charging, is connected to the positive terminal of the charging device?

(33) What percentage is usually added to the ampere-hours of a storage-battery when the time of charging is being calculated?

(34) If an accumulator has a capacity of 500 ampere-hours and is charged at the rate of 5 amperes, how many hours are required?

(35) Does the E. M. F. of an accumulator have any effect on that of the charging current?

(36) What is meant by the "gassing" of a storage-battery, and when does it take place?

(37) Why is it important that the rate of charging and discharging a storage-battery be kept within certain limits?

(38) If a lighting circuit is used for charging an accumulator at the rate of 5 amperes, and incandescent lamps are used as resistance, how many 16-candle-power lamps will be required, and how are they arranged?

(39) What is the function of a rheostat?

(40) What purpose does a motor-generator serve?

(41) Why is it that a current of electricity resists a sudden starting and stopping?

(42) If a current, while flowing from left to right in a conductor, is suddenly stopped, what influence will this have on another conductor parallel to the first?

(43) What is meant by an extra current?

(44) What means are used for making the interruption of a current approximately instantaneous?

(45) (*a*) What happens when the armature *H*, Fig. 14, is attracted by the core *C*? (*b*) What path does the extra current follow?

(46) If the gap in a secondary circuit is too large for the closing current to bridge, but small enough for the breaking current, what will be the nature of the current in the secondary coil?

(47) If the diameter of the wire used in the secondary coil is greater than that in the primary coil, and the number of windings is less, how is the pressure in the secondary coil relative to that in the primary?

(48) Is it sufficient to judge the efficiency of a coil simply by measuring its sparking distance?

(49) What determines the power of a coil?

(50) What is the objection to a simple spring interrupter?

(51) In what respect does an independent spring interrupter differ from an ordinary spring interrupter?

(52) How does the rate of interruptions affect the current-strength through the primary coil?

(53) Why is it important that a current should not be sent through the primary coil before the interrupter is in action?

(54) If the discharge of a storage-battery proceeds too far, what effect does it have?

(55) From what part of a Roentgen ray tube do the rays proceed?

(56) What effect does the size of the focusing point have on the sharpness of the skiagraph?

(57) What is the function of the anticathode?

(58) If the vacuum of a tube is varied, what effect has this on the character of the rays?

(59) In order to get the most use from a Roentgen ray tube, what should be the condition of its vacuum when new?

(60) What is the advantage of a self-regulating tube?

(61) To what do the terms "hard" and "soft" refer when applied to a Roentgen ray tube?

(62) To differentiate between dense substances what should be the condition of the tube?

(63) If maximum differentiation is desired in substances of small density, should a soft or a hard tube be used?

(64) If under any conditions maximum differentiation is the aim, what should be the penetrating quality of the rays relative to the density of the integral parts?

(65) What effect has a series spark-gap when inserted in a Roentgen tube circuit?

(66) Does the specific gravity of a substance have any effect on its permeability to Roentgen rays?

(67) What is the relative transparency of glass and lead?

(68) If maximum definition of an object is desirable, what position should it occupy relative to the fluorescent screen or sensitive plate?

(69) When it is required to remove the confusing effect of certain parts, how should they be placed with regard to the sensitive plate?

(70) Should it be of advantage to have all the constituent parts appear with nearly equal definition, what position should the Roentgen ray tube occupy relative to the object?

(71) Do the surroundings of a Roentgen ray tube take any part in radiating Roentgen rays?

(72) What is the cause of the distortive effect of Roentgen rays?

(73) To prevent distortion in a skiagraph of any particular object, what position should the same occupy relative to the tube?

(74) In order to locate a bullet in a body a double exposure has been made while the tube was 14 inches above the sensitive plate. During either exposure the tube occupied a position 6 inches to the left and right, respectively, of the zero point in Fig. 43. The distances between e and f and the center of the plate are 3 and 4 inches, respectively; find the distance of the bullet above the plate and the distance between the bullet and the center line $m_0 n_0$, Fig. 46.

(75) What other means, founded on the motion of the object relative to the Roentgen ray tube, are there for locating the position of an object?

(76) To receive the full benefit of fluoroscopic examination, what should be the condition of the operating room and of the operator's eyes?

SKIAGRAPHY.

EXAMINATION QUESTIONS.

(1) What does a skiagraph really represent?

(2) What means are there at present for making visible the shadows produced by Roentgen rays?

(3) Name the active ingredients in the gelatine coating of a sensitive plate.

(4) Why is a red light used for the dark room?

(5) When handling sensitive plates before exposure and development, what precautions should be taken to avoid misleading marks?

(6) What precautions should be taken when storing sensitive plates?

(7) Why is the sensitive layer of a Roentgen ray plate placed so as to face the tube?

(8) What purpose does the intensifying screen serve?

(9) Does the intensity of the Roentgen rays vary in the same ratio that the distance between the tube and plate is varied?

(10) What other factors, besides distance, affect the length of exposure?

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(11) What is the process of "developing" a sensitive plate?

(12) In covering a plate with the developer, what precautions must be taken?

(13) When an overexposure has been made, is there any difference whether this has been produced by means of a hard or a soft tube?

(14) Why should the aim be to produce contrasts in developing the skiagraph?

(15) If an overexposure has been made, what means should be used to counteract the rapid development of a skiagraph?

(16) If an underexposure has been made and the development proceeds too slowly, what can be done to accelerate the development?

(17) By what signs will a skiagraph indicate an overexposure or an underexposure?

(18) While observing the appearing image of a skiagraph undergoing development, how can a distinction be made as to whether it is overexposed or underexposed?

(19) What precautions should be taken while handling the fixing solution?

(20) What is the difference between a positive and a negative?

(21) In viewing an ordinary negative and a skiagraph from their glassy side, state what difference is found in regard to the position of the integral parts.

(22) In order to, in either case, receive a correct impression of the relative positions of the parts, how should they be viewed?

(23) If a positive is made from a skiagraph, what is there to be said regarding the position of the parts shown in the same?

(24) Explain the difference in perspective between a skiagraph and a picture of the same object.

(25) In viewing a skiagraph from its film side, why are the parts with clear outlines usually overlapped by other parts shown more or less diffusely?

Practical Applications of Roentgen Rays.

EXAMINATION QUESTIONS.

(1) How are the margins of the orbit, the nasal bones, and the antrum Highmori best skiagraphed?

(2) Describe the method of locating a bullet in the eye.

(3) What is the best position of the patient to take a skiagraph of the neck?

(4) What may be said of the value of Roentgen rays in locating foreign bodies in the throat?

(5) What is the special value of the fluoroscope in examining the intrathoracic organs?

(6) Why is the image of the anterior aspect of the ribs diffused in anterior irradiation?

(7) In what position is the heart best skiagraphed?

(8) What may be said of a clear skiagraph of the dorsal vertebræ?

(9) Why are the outlines of the heart better seen during fluoroscopy than in skiagraphy?

(10) What is the advantage of Roentgen rays in the early stage of aortic aneurism?

(11) What may be said of fluoroscopy and skiagraphy in the examination of mediastinal tumors?

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(12) State the value of Roentgen rays in determining the treatment of traumatic pericarditis.

(13) How is a pyothoracic cavity skiagraphed?

(14) How are the outlines of the stomach made visible?

(15) State the principal benefits of abdominal skiagraphy.

(16) What is the most important requisite for skiagraphic success in the diagnosis of cholelithiasis?

(17) In skiagraphing for cholelithiasis, state (*a*) the position of the patient; (*b*) the time of exposure; (*c*) the direction of the rays.

(18) Why must great care be taken to place the tube in the proper direction when exposing for cholelithiasis?

(19) In skiagraphing the kidneys, state (*a*) the quality of the tube used; (*b*) the position of the patient; (*c*) the time of exposure.

(20) State the greatest usefulness of Roentgen rays in renal disease.

(21) Who first skiagraphed a renal calculus?

(22) Is a good skiagraphic plate conclusive evidence in the diagnosis of renal calculi?

(23) What is the chief characteristic of a reliable renal skiagraph?

(24) In what position is a vesical calculus best skiagraphed?

(25) Why should a lateral exposure always be made in skiagraphing for vesical calculus?

(26) How may the outlines of tumors of the stomach be skiagraphed?

(27) State the value of skiagraphy in determining the treatment in spina bifida.

(28) State the use of Roentgen rays in gynecology and obstetrics.

(29) In skiagraphing the pelvis, state (*a*) the position of the patient; (*b*) the quality of tube; (*c*) the time of exposure.

(30) State the difference between the skiagraphs of a normal hip and a hip in the first stage of tubercular inflammation.

(31) State the value of Roentgen rays in the early stage of the different inflammatory processes of the hip-joint.

(32) Describe a skiagraph of arthritis deformans.

(33) State the differences between the skiagraphs of a normal knee-joint and a tubercular knee-joint.

(34) Of what service are Roentgen rays in determining the treatment of osteomyelitis?

(35) What is the characteristic skiagraphic feature of osseous cysts in contradistinction to osteosarcoma?

(36) State the best position to skiagraph (*a*) the metatarsal bones; (*b*) the tarsal bones.

(37) Why should two different skiagraphs in two different positions be always taken in every case of suspected fracture?

(38) What is necessary to always bear in mind in interpreting the skiagraphs of children?

(39) How is a good skiagraph of a shoulder-joint best obtained?

(40) What is the significance of a good skiagraph of a fracture in estimating the degree of functional disability?

(41) What complications of Colles' fracture have the Roentgen rays shown to be of quite frequent occurrence?

(42) If there is no displacement of the fragments, what may be said of the fracture line if the skiagraph is taken immediately after the accident?

(43) What is the quality of the tube required to reproduce the presence of a fissure in bone?

(44) What has skiagraphy proved to be the cause of bony ankylosis following Colles' fracture?

(45) State the services rendered by Roentgen rays in diseases and injuries of the hand.

(46) What may be said of skiagraphy in differentiating the various inflammatory processes from new growths of bones and joints?

(47) When utilizing the rays for therapeutic purposes, state (*a*) the quality of the tube; (*b*) the time of the first exposure; (*d*) the frequency of the exposures; (*e*) the means of protecting the healthy parts.

(48) In what class of diseases is Roentgen ray therapy now generally used?

(49) What qualifications are necessary in order to correctly interpret skiagraphs?

(50) What are the most frequent dental uses of Roentgen rays?

(51) What are the advantages of the film in dental skiagraphy?

(52) At what distance from the film is the tube generally placed in dental work?

Physics of Light and Cautery

EXAMINATION QUESTIONS

(1) Into what forms may the energy of an electric current be changed while passing through a circuit?

(2) What difference is there between the molecules of different substances with regard to the quantity of heat required to heat them to the same temperature?

(3) What influence has the individual weight of a molecule on the number of molecules required to make up a certain mass?

(4) If a certain mass contains a great number of molecules, how will this influence the amount of heat necessary to raise it to a given temperature?

(5) How does the specific gravity of a substance affect the amount of heat that it will take up before it has attained a given temperature?

(6) What is meant by the *specific heat* of a substance?

(7) What is understood by a *calorie?*

(8) If it requires 60 calories to raise the temperature of a platinum wire 10° C., how many calories does it take to produce an equal rise in the temperature of a piece of copper wire of the same weight?

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(9) (*a*) If a current of 10 volts and 5 amperes passes through a conductor, how many calories per second are developed in it? (*b*) How many foot-pounds per second will these calories represent?

(10) A current of 8 amperes passes through a resistance of 2 ohms for 1 minute. How many calories have been developed?

(11) If a conductor first transmits a current of 4 amperes and later on a current of 8 amperes, how many more calories are developed in the latter case?

(12) When the heat developed in one part of a conductor is leaking along the conductor to other parts, by what means does this loss take place?

(13) If the small incandescent lamp of a cystoscope inserted in a cavity of the body heats the surrounding walls, by what means, in this instance, is the heat transmitted to said walls?

(14) How does a resistance-coil of iron or copper heat the surrounding air?

(15) When an electric current is passing continuously through a conductor and constantly transforms part of its energy into heat, what limits, in general, the final temperature that the conductor is able to attain?

(16) A copper conductor having an initial resistance of 120 ohms has its temperature raised 80° C. What increase in resistance has taken place?

(17) If it is desirable to use a conductor whose resistance is unaffected by changes in its temperature, what material would be suitable for such conductor?

(18) If a carbon rod has a resistance of 5,000 ohms, and its conductivity is increased at the rate of .03 per cent. per degree centigrade, what will be the resistance when its temperature is raised 70° C.?

(19) Some salt is added to a vessel of water whereby its resistance is reduced to 500 ohms. Supposing that it suffers a decrease in resistance of .6 per cent. per degree centigrade increase in temperature, what will be its resistance when the temperature of the solution has risen 40° C.?

(20) If part of an electric circuit is heated, has this part any effect on the remaining part of the circuit, as regards current-strength and temperature? Give reasons.

(21) Part of a heated conductor is suddenly dipped into cold water. What effect has this on the total resistance of the circuit? Does it affect the temperature of the parts not submerged?

(22) What important adjunct should there be in every cautery circuit to insure a constant temperature of the cautery?

(23) If a great number of watts should be dissipated in the form of heat in an electric circuit of low resistance, what other factor must be increased to obtain a sufficient quantity of heat?

(24) If the resistance of a cautery is very low, why is it that the resistance of other parts of the cautery circuit must be still lower?

(25) Is there any objection to having a cautery circuit with a resistance just low enough to give sufficient current to the cautery and with only a small adjustable resistance in the circuit? Give reasons.

(26) What should be the properties of voltaic cells used for cauteries?

(27) A cautery circuit, in which the joint resistance of the cautery and conductors is .04 ohm, is operated by three cells in parallel, each having a resistance of .03 ohm and an E. M. F. of .7 volt. What will be the current-strength in the circuit?

(28) What would be the current-strength if the same cells were arranged in series?

(29) What objection is there to using a direct current from a lighting circuit for cautery purposes?

(30) Mention a method by means of which a direct lighting current may be used economically for cauteries.

(31) Why is the cautery transformer, illustrated in Fig. 5, not as efficient as some other forms where the coils are imbedded in laminated iron?

(32) What precaution should be taken when using a cautery-snare to prevent the overheating of the platinum wire?

(33) A certain incandescent lamp requires 4 watts per candlepower. If the total candlepower is 8 and the voltage 10, what current-strength is required to operate the lamp?

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